



Cornell **CALS**
College of Agriculture and Life Sciences

*Meeting New York State's Energy,
Environmental and Economic Goals While
Strengthening Dairy Farms Through the
Widespread Adoption of Manure-Based
Anaerobic Digestion Technology
Working Paper*

Prepared by:

Jennifer Pronto

Curt Gooch, P.E.

Peter Wright, P.E.

PRO-DAIRY Program

Cornell University, NY

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Abbreviations:

AD – anaerobic digestion
 ADS – anaerobic digester system
 Btu – British thermal units
 CF – capacity factor
 CH₄ - methane
 CO₂ – carbon dioxide
 GHG – greenhouse gas
 GWh – giga Watt hour
 K – Potassium
 kWh – kilo Watt hour
 MMTCO₂e – million metric tons of carbon dioxide equivalents
 MTCO₂e – metric tons of carbon dioxide equivalents
 MW – mega Watt
 MWh – mega Watt hour
 N - Nitrogen
 N₂O – Nitrous oxide
 P - Phosphorus

Acronyms:

BMP – best management practice
 CAFO – concentrated animal feeding operation
 CEF – Clean Energy Fund
 CES – Clean Energy Standard
 CHP – combined heat and power
 CNG – compressed natural gas
 CNMP – Comprehensive nutrient management plan
 EPA – Environmental Protection Agency
 GWP – global warming potential
 ILR – Cornell School of Industrial and Labor Relations
 LNG – liquid natural gas
 MSW – municipal solid waste
 NYS – New York State
 NYSERDA – New York State Energy and Research Development Authority
 REDC – Regional Economic Development Council
 REV – Reforming the Energy Vision
 RNG – renewable natural gas
 USDA – United States Department of Agriculture

Executive Summary

Anaerobic digestion in New York State has effectively treated dairy manure for decades, and continues to be implemented, though more slowly, due mainly to reduced public funding and loan opportunities, and poor return on investment for farmers since its benefits to society are not monetized. The technology has the potential to have a significant impact on the goals of recent State policies and initiatives looking to reduce greenhouse gas (GHG) emissions, increase distributed, clean energy sources, managing organic waste, and bolster upstate economic activity – all of which, fall under the myriad of benefits that anaerobic digestion (AD) technology holds claim to.

New York State, through the leadership of Governor Andrew Cuomo has established challenging renewable energy goals and greenhouse gas reduction goals. The State's renewable energy goal is to increase renewable energy to 40% by 2030. The greenhouse gas reduction goal is to reduce greenhouse gases by 50% from 1990 levels also by 2030. Manure-based anaerobic digestion systems have a role to play in both of these goals. Currently, the 28 ADs in operation in NYS have a generation capacity of 13.1 MW of renewable electrical energy. In total, these 28 systems (installed from 1998 – 2016) now have the potential to reduce almost 120,000 MTCO₂e per year, which is equivalent to removing more than 25,500¹ cars from the road. If the manure from half the milking cows in the State was processed in AD systems, 528,000-MWh of electricity could be generated annually and over 1,000,000 MTCO₂e per year could be captured and destroyed, in effect, removing almost 225,000 cars from the road.

There are a number of initiatives by the Governor that address both these goals and anaerobic digestion on farms including: Methane Reduction Plan, Reforming the Energy Vision, Clean Energy Standard, Clean Climate Careers, Regional Economic Development Councils, Dairy and Yogurt Summit, and the Clean Energy for Agriculture Task Force. Each of these initiatives recognize that the renewable energy and greenhouse gas reduction of anaerobic digestion supports the State's goals.

Anaerobic digestion systems operated with an emphasis on GHG control in New York State can reduce CO₂e by 2.94 MT/cow annually. Each ton of methane has a global warming potential 34 times that of carbon dioxide. By combusting the methane to produce renewable energy this also significantly reduces the global warming potential beyond the fossil fuel replacement. Most CO₂ emissions from dairy farms result in a net zero impact on GHG emissions, since the CO₂ emitted originally came from CO₂ removed from the atmosphere by photosynthesis. Most other renewable energy technologies only reduce greenhouse gas emissions by reducing the fossil fuels used for traditional energy generation. This is a 3x reduction in GHG per kWh that anaerobic digestion has over most other renewable energy sources.

The capacity factor (CF, a quantitative factor that indicates the actual amount of energy produced by a system in a given period of time to the maximum amount that could have been produced in the same period of time) for wind and solar are much lower than that of anaerobic digestion. Wind and solar only operate intermittently, limited by nature, whereas anaerobic digestion systems have the potential to operate continuously (with meticulous control and maintenance). Wind power depends on weather

¹ Value calculated using EPA's estimated value of 4.7 MTCO₂ to represent the emissions from a typical passenger vehicle in the U.S (EPA, 2017c).

conditions and location, whereas solar depends on panel orientation, weather, time of day, and time of year. When the impact of the CF is included for renewable energy systems, anaerobic digestion is competitive with solar and wind on a capital cost basis and is even likely a lower cost alternative when energy storage is included in system capital costs.

Manure-based anaerobic digesters are well-positioned to receive significant amounts of diverted organic waste from landfills preserving landfill capacity and also reducing the GHG emissions from landfills, producing renewable energy, and recycling nutrients in the organic matter that are needed to grow new crops. There is tremendous potential for future growth in AD based on-farms in NYS; if the manure from half the milking cows in the State was to be treated by anaerobic digesters, more than 1,000,000 tons of CO₂e would be reduced each year. If food and beverage entities in the State diverted their waste to farm digesters, an additional 2.28 billion ft³/year of methane (New York State, 2009) could be produced, captured, and used to generate 240 million kWh of electricity, and reduce at least 146,000 tons CO₂e emissions. If the manure from half the milking cows in the State was to be treated by anaerobic digesters, 528,000-MWh of electricity could be generated annually. If food and beverage entities in the State diverted their waste to farm digesters, a total of 768,000-MWh of renewable electricity could be produced annually. The NYS Energy Plan at this time does not recognize the upstream greenhouse gas reductions from anaerobic digestion. Since anaerobic digestion is unique in this area the potential benefits may go unrealized.

Another option of manure-derived biogas is to replace fossil-fuel based methane and use it for all the same uses, including for renewable natural gas fueled vehicles. There is the potential to store the methane to use on demand to meet peak electric generation needs. These potentials for storage and transportation uses are not as available from other renewable energy systems.

Economically stable dairy farms are a significant boost to the upstate economy. New York is currently the third largest dairy state in the country, and is positioned to remain in this position for the foreseeable future; milk is the number one agricultural commodity produced in NY. Dairy farms provide jobs both directly and indirectly. Additional enterprises could have a symbiotic relationship with an on-farm anaerobic digestion system including: food or grain processing, greenhouse production, and lumber drying.

There are several New York State agencies that have a vested interest and programs that directly impact manure-based anaerobic digestion. These include: New York State Energy and Research Development Authority, Department of Environmental Conservation, Department of Public Service, and the Department of Agriculture and Markets. Anaerobic digestion impacts the energy sector in both renewable energy production and distributed energy production. Environmental areas that anaerobic digestion impacts include air and water quality, climate change and resiliency, and organic waste management. Each of these agencies support anaerobic digestion but there is not a program to compensate the anaerobic digestion process for the full benefits that it provides society.

Currently operation and maintenance costs ranging from \$0.03 to \$0.05/kWh for the engine-generators will force farms with existing anaerobic digesters to stop generating, foregoing the potential for both renewable energy and greenhouse gas reduction. Without monetizing the environmental benefits from anaerobic digestion New York State would lose out on an excellent opportunity to demonstrate environmental responsibility. Anaerobic digestion technology is flexible, nimble and dynamic in ways that it can respond to peak power loads, meet base line power needs, and be a

replacement energy for other renewable energy sources when they are not operating to capacity. With a relatively small investment and State leadership, these anaerobic digestion benefits can be expanded, being a large win for the State, regional economic development, GHG, and clean water goals.

Next Steps:

To facilitate anaerobic digestion technology's benefits it would be best to monetize them in a specific way as opposed to each applicable initiative progressing under each relevant State agency independently providing incremental support.

This Working Paper will be updated as new information is obtained on: the GHG emissions from manure management, the operation of on-farm AD, and the actual environmental value of renewable energy from AD is included in the value stack

Introduction

This document was prepared to highlight the employment of anaerobic digestion (AD) technology in the current energy- and climate-focused initiatives in the State, and to call out its absence where it would be an effective solution if employed. If readers require technical background information regarding AD technology, it is provided in Appendix B, and includes topics such as the basics of AD operation, energy generation, and greenhouse gas reductions.

New York State has established challenging renewable energy goals and greenhouse gas reduction goals. There are multiple ways this technology is able to effectively contribute to the most highlighted NYS energy goals recently outlined by Governor Andrew Cuomo, as shown in **Error! Reference source not found.**, and as explained in depth in this document.

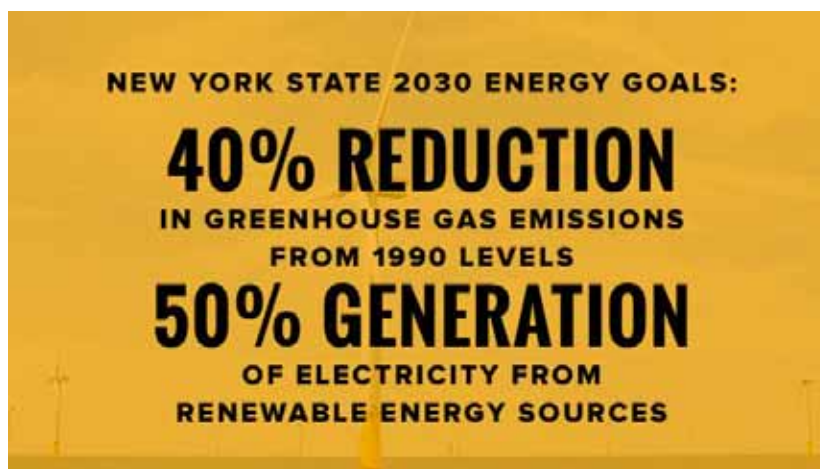


Figure 1. NYS current energy goals from the 2015 New York State Energy Plan under Governor Andrew Cuomo

Benefits of Manure-Based Anaerobic Digestion

Historically, anaerobic digestion has been used as a manure management strategy by dairy farms in the State to treat and facilitate storage and recycling of manure by controlling odors, reducing weed seeds and pathogens, and liquefying for easier pumping prior to recycling the effluent back to cropland providing vital nutrients for crop production.

The direct benefits immediately realized from the most basic employment of this technology include: odor reduction, improved nutrient management, facilitated long-term manure storage and future application, reduced methane emissions, and energy and heat generation. Subsequent benefits that are provided by these effects include: improved neighbor and community relations, reduction of purchased commercial fertilizer, improvement in water quality, reduction of manure application costs, and sale of excess heat/electricity to the grid. Furthermore, these benefits have farther-reaching positive societal impacts including: the ability to recycle organic wastes for energy and nutrients as well as GHG reduction, improvement in rural economies, increased likelihood of family-farms survival, enhancement of recreation and tourism, improved soil health, increased crop yields, reduction of dairy's impact on climate change, and participation in providing distributed energy to the main power grid. Each of these benefits is listed in Appendix A along with a brief description.

As just stated above, the original reasons for employing manure-based AD on NYS farms was odor control and energy generation; however, the resulting chain of positive impacts leads to a vision such as this: *an enhanced quality of life for NYS residents that includes the ability to enjoy an affordable, clean, distributed energy solution that has reduced our State's impact to global climate change and increased our State's homegrown, dependable supply of energy.* The resulting web of positive impacts based on the use of farm-based AD is shown in **Error! Reference source not found..** Ultimately, the benefits of manure-based anaerobic digestion contribute to human health and quality of life.

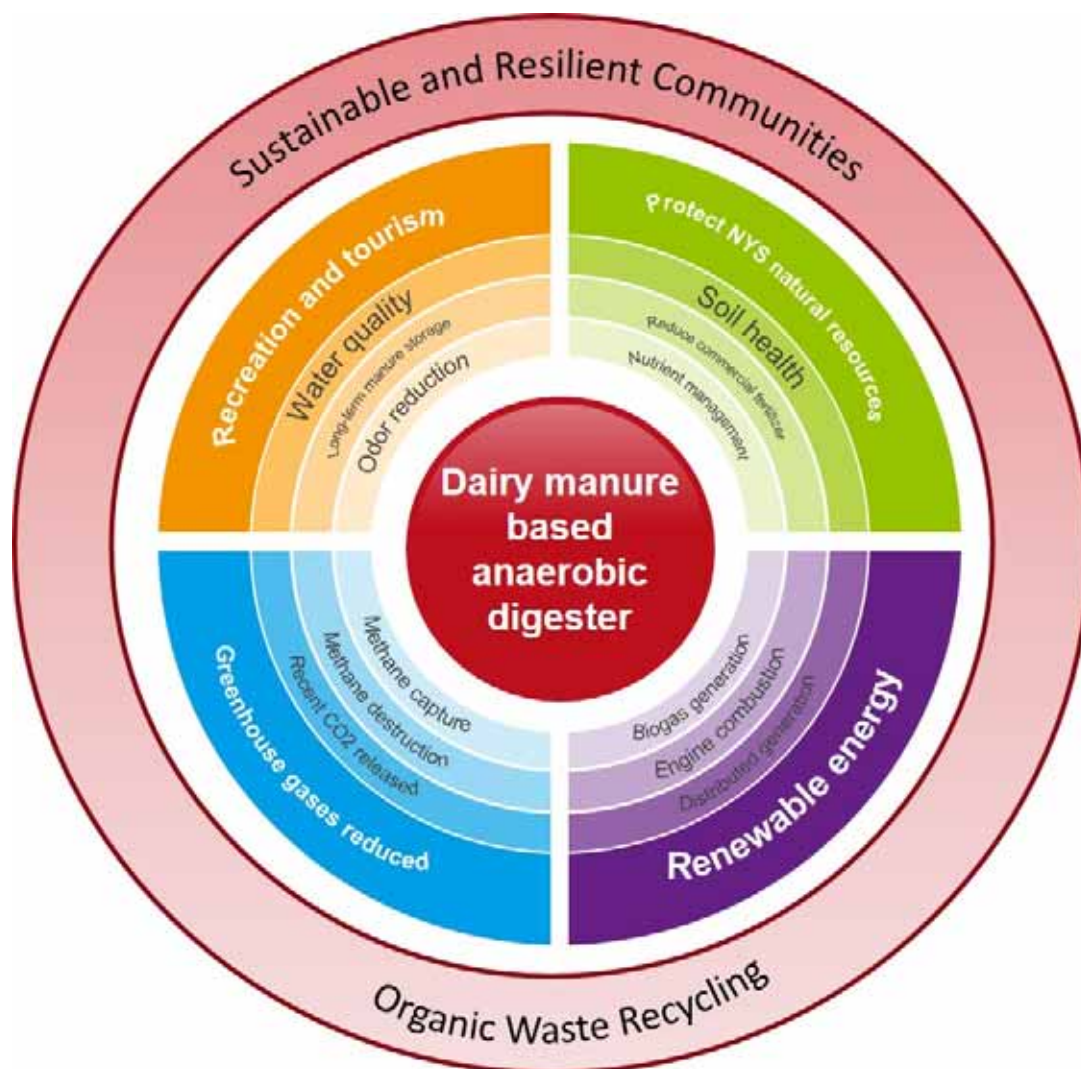


Figure 2. Circular diagram representing the wider impacts of farm-based anaerobic digestion beginning with direct farm benefits, and ending with the associated societal benefits that are similar to those reflected in the current REV plan.

As a manure treatment strategy recognized worldwide, anaerobic digestion conveys benefits to society and the environment, yielding a vision equivalent to what is called for in the most recent version of the REV plan. However the Energy Plan provides very little information on this technology as a potential solution.

AD technology has certain benefits which make it an attractive option to provide increased distributed generation capacity, namely, continuous flow of energy production, and a storable product (i.e., biogas) prior to the energy generation step. Additional advantages of implementing AD as a renewable generation technology include:

- 1) biogas generation from an ADS is independent of siting, meaning geography and location of the system do not affect energy production, as it does with other renewable technologies
- 2) biogas generation is also independent of time, meaning season and time of day do not affect energy generation, as it does with other renewables
- 3) AD vessels can be designed with the capacity to recycle other organic wastes, thus diverting them from landfills and eliminating their associated GHG emissions
- 4) biogas generation can increase with the manipulation of substrates used in the system, at the control and discretion of the system operator
- 5) the ADS has a comparably high capacity factor (Thi, 2016)
- 6) renewable energy generated by other distributed generation technologies is not associated with the environmental and economic benefits offered by the integration of an ADS to an agricultural setting

Many engineers and scientists have concluded that there is no ‘silver bullet’ that will supply us with 100% of the renewable energy we seek (Kutz, 2014). There is not one or even two solutions that exist that will allow us to comply with the goals that have been set for the State, however, there is a multitude of technologies that should be pursued in parallel, while continuing the research and development to enhance existing technologies and to discover new ones. The many technologies that have already been proven, and that are already employed, need to *all* be considered and supported to promote a diversified, resilient energy profile for the State. In line with facilitating access and lowering prices of electricity across the State, the reliability and resiliency of the grid is equally as important, as is spelled out in the Energy Plan. Longer power outages result in greater economic impacts to customers and businesses, and they are on the rise across the country (NYS Energy Planning Board, 2015a). The REV promotes the idea of developing ‘community microgrids’ which would incorporate locally generated clean energy, including that from the 28 ADS in operation across the rural areas of the State. A community microgrid has the ability to maintain electricity supply at critical facilities when the main power grid fails, and to offer a cost-effective complement to the central grid at all other times or normal operation.

The agriculture sector in New York State is a significant contributor to the State economy, the State’s total agricultural production was valued at over \$5.4 billion in 2012 by the National Agricultural Statistics Service. There are over 35,500 farms in New York, occupying about 25 percent of the State land. NY State is a major producer of many agricultural products; milk from cows is the largest segment of the agricultural sector (NYSERDA, 2017a). If all 156 of the large dairy CAFO’s in NYS possessed an AD system, they could reduce the manure-based GHG emissions by 74%, from 2014 estimates by NYSEDA (NYSEDA 2017a).

It is important to have a good understanding of the structure of New York’s almost 5,000 dairy farms. Figures from the 2012 Census of Agriculture, prepared by the USDA’s National Agricultural Statistical Services, shows that the average herd size in New York is still relatively small, at 121 cows. This size of a farm is generally not a great target for farm AD, but can and will become a great utilizer of other renewable energy production strategies such as solar and small wind. However, 5% of New York’s dairies

have 500 or more cows, and produce slightly over 50% of New York's entire milk supply. An additional 5% of New York dairies have between 200 to 500 cows, and produce 14% of New York's milk supply. These medium to large size farms are a direct target for farm AD technology, and are critically important not just for their economic impact, their potential to reduce GHG emissions, but also because of their substantial role in supplying milk products to Northeast consumers. These farms are also prime candidate locations for receiving biomass diverted from landfills, which would further reduce anthropogenic GHG emissions creating an additional societal environmental benefit.

In addition to the clear benefits anaerobic digestion technology possesses to assist in meeting the State's goals, it is important to also recognize the synergistic benefit the support of this technology has on the dairy farms in NYS. New York is currently the third largest dairy state in the country, and is positioned to remain in this position for the foreseeable future; milk is the number one agricultural commodity produced in NY. For these reasons, it is a good sector for the State to invest money, and to keep dollars local within the State. However, challenges are on the rise for dairy farms in the State, who are facing stagnate prices, increased costs, increased regulations, and labor shortages. AD technology offers significant benefit to the farmstead, as well as many different revenue-generation schemes that can co-operate with manure treatment and energy generation.

Since the interconnections among state agencies are complex, and since many initiatives fall under the direction of multiple agencies, a roadmap for this document is provided in **Figure 3** to facilitate use of the content. The two main sections are 1) Governor Cuomo's key initiatives and 2) NYS agencies with programs relevant to AD, where the sub-headings include the appropriate initiatives and agency directives.

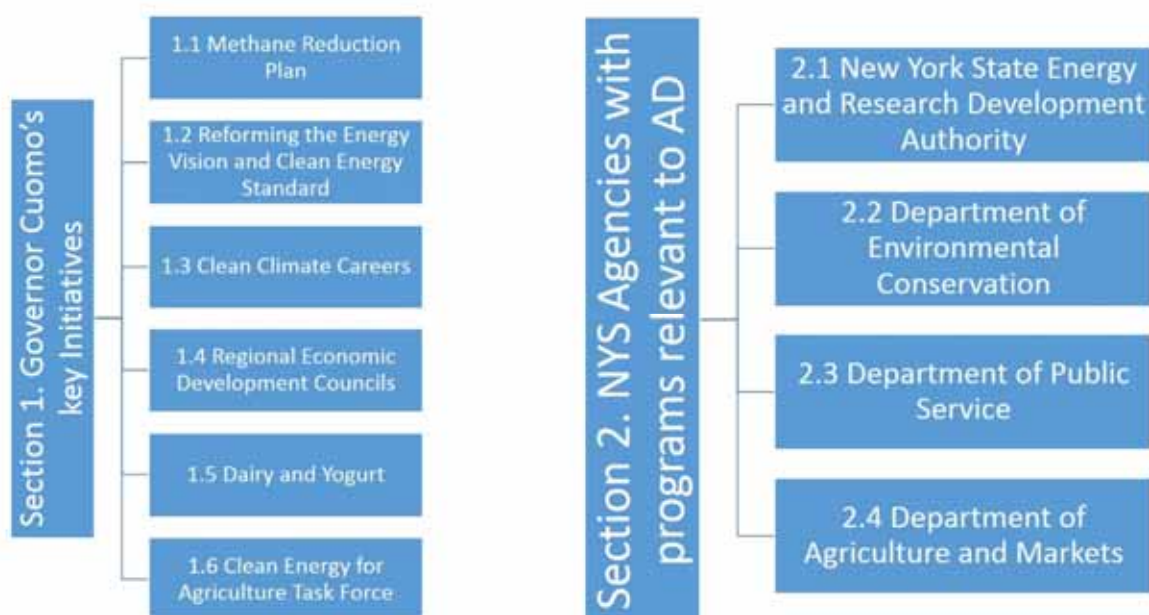


Figure 3. Document layout by section and sub-heading

In addition, **Table 1** is provided to summarize the agencies and relevant initiatives mentioned in detail throughout this document, and to summarize the ways in which AD contributes to meeting the target goal.

Table 1. Agency and initiative summary table

Agency	Plan/goal/initiative	Target	How AD contributes
DAM, DEC, DPS, NYSERDA	REV and Methane Reduction Plan	Reduce GHG emissions 40% from 1990 levels	The process of AD produces methane in a confined vessel, which is used for renewable energy generation, resulting in 3x the GHG reduction of any other renewable energy technology.
DPS, NYSERDA, NYPA, PSC, NYPA	REV	Supply 50% of the total electricity generation from renewable energy sources by 2030	ADs produce biogas, which contains methane, and can be combusted to produce renewable electricity and heat. Currently, operational AD systems in the State have a generation capacity of 13.1 MW capable of producing 103,000 MWh per year, but if the manure from half the milking cows in the State was to be treated, the capacity could increase to 528,000-MWh per year.
DEC, NYSERDA	Beyond Waste	Reduce organic waste disposal in landfills to 0.6 pounds per person per day by 2030	Partnering farm ADs with landfill diversion of organic waste is beneficial because: 1) organic waste is treated effectively when co-digested with manure, 2) renewable energy generation is increased, and 3) the process recycles naturally occurring nutrients in food waste to a farm's land base, therefore reducing the need for commercial fertilizer use (a high GHG related manufacturing process).

DAM: Department of Agriculture and Markets

DEC: Department of Environmental Conservation

DPS: Department of Public Service Also known as PSC (Public Service Commission)

NYPA: New York Power Authority

NYSERDA: New York State Energy and Research Development Authority

When analyzing the potential for AD implementation, it is helpful to have other technologies to compare and contrast. Solar and wind are the two technologies that the State is currently concentrating on, since they are listed to have the largest growth potential (NYSERDA, 2014), they are contrasted in **Table 2** to compare select values to AD technology.

Table 2. Capacity factor, GHG reductions, and Installation cost for wind, solar and AD

	Capacity factor	GHG reductions factor	Total capital cost	Adjusted total capital cost⁴
Wind	0.25 ^a	1 x (Fossil fuel avoided)	\$3.2 million/MW ²	12.8 million/MW
Solar	0.15 ^a	1x (Fossil fuel avoided)	\$3.8 million/MW ³	25.3 million/MW
AD	0.90 ^b	3x (Fossil fuel avoided and captured/combusted CH ₄ emissions) ⁵	\$7.2 million/MW ¹	8.0 million/MW

^a Source: NYISO, 2017

^b Source: Biogas Weser-ems, 2014

¹Price in 2012 dollars

²Price for commercial level installation, in 2012 dollars

³Price for small commercial upstate, in 2012 dollars

⁴Capital cost adjusted for capacity factor to show capital cost per average MW production.

⁵Manure-based systems only

Capacity Factor

The capacity factor (CF) is a ratio of the energy that was produced in a given time frame to the maximum energy that could have been produced over that same period of time. A CF of less than 1.0 indicates that the energy generation mechanism did not run at full speed and/or did not run continuously. The CFs shown in **Table 2** for wind and solar are much lower than that of AD, because they only operate intermittently, limited by nature, whereas AD systems have the potential to operate continuously (with meticulous control and maintenance). Wind power depends on weather conditions, geography and time of day, whereas solar depends on panel orientation, weather and time of day. In the United Kingdom where commercial digester systems utilize a significant portion of food waste and/or energy crops, the AD systems are installed, optimized, and maintained in a fashion to maximize power output. In this setting, the CFs of the top 20 most efficient AD systems in the United Kingdom is equal to 0.882, with the top system exhibiting a 0.97 CF (Biogas Weser-ems, 2014). A NYS AD systems with a monetary motivation to reduce GHG emissions can be managed to achieve at least a 0.90 CF.

Greenhouse Gas Emission Reductions

The GHG reduction factor shows the reduction in GHG emissions for each unit of energy produced. Each of the renewable energy sources; solar, wind, and AD, replace the fossil fuels that normally would be required to produce energy. However, AD also captures and destroys some of the high GWP methane that is created by emissions from long-term manure storage. This additional GHG reduction creates a 3x reduction over other renewable energy technologies, when fossil fuels only are displaced.

Capital Cost

The capital costs in the last column are the total capital costs times the CF. Since both wind and solar are limited by the physical presence of wind and sunshine, their adjusted capital cost per average unit of energy produced is higher as they are off-line a considerable part of the time. AD in contrast can have a much higher CF based on management. This provides an adjusted capital cost much closer to the total capital cost. This adjusted cost assumes the same life span for each technology. Operation and maintenance of the engine generator is one disadvantage for AD technology. Current estimates range from \$0.03 to \$0.05/kWh for AD systems. When energy storage is taken into consideration for renewable energy technologies that have system limiting CFs and energy storage is then used to allow for renewable energy to be available at other items of the day, the difference in system costs increases.

Dairy-Based Greenhouse Gas Emissions and National Dairy Industry

Proactive steps to reduce GHG emissions and to maximize renewable energy generation are not only being pursued in NYS, but the national dairy check off organization, Dairy Management Incorporated, committed to pursuing a more sustainable industry by creating the Innovation Center for U.S. Dairy². Their goal is to pursue the responsible production of nutritious dairy products in a more sustainable food system. Several initiatives aimed mainly at reducing GHG emissions, have been put in place with substantial progress over the past several years. Initiatives are aimed at all portions of the dairy milk supply chain, but the most noteworthy tackle the largest emission contributors, including manure management and enteric methane emissions. Anaerobic digesters have been called out as the primary opportunity to reduce dairy's GHG footprint, as it is the second largest GHG contributor in the milk supply chain, and because the largest contributor, enteric fermentation, will take many years to develop solutions, and will likely have a limit in terms of how much it can be reduced. Food processors will continue to examine the GHG impact of their raw ingredients to demonstrate to consumers the sustainability of their products to consumers. A reduced carbon footprint from milk will be valued through this effort.

Anaerobic Digestion and State Initiatives

Benefits to the citizens of New York are at the core of many of the initiatives implemented by the Governor – efforts are underway to reduce energy costs, to facilitate the use of alternative, clean transportation methods, to improve air quality, to create jobs and to provide resources that will support resilient communities so that they may thrive. In 2010, one of the largest gatherings of dairy-farm based AD technology stakeholders took place at the New York Cow Power Summit (Syracuse, NY), and one of the results was this unified community vision shown in **Figure 4**, centered on a dairy farm employing anaerobic digestion to treat manure, to create renewable energy, and to reduce GHG emissions. As is the case with many of the state initiatives, the core of this illustration is the community, while materials, money and benefits flow both ways between the farm and the community. For example, the local cheese making plant uses milk from the dairy farm and heat from the engine generator-set to produce cheese, and sends their processing waste to be treated in the AD. The local school runs on renewable electricity produced by the AD, and sends organic food waste to be incorporated to the AD to increase the energy produced. This resulting vision is based off the integration of AD systems in Europe, specifically in Germany and Denmark.

² <https://www.usdairy.com>

Section 1. Governor Andrew Cuomo's Key Initiatives

"Climate change is a reality, and not to address it is gross negligence by government and irresponsible as citizens." - Governor Cuomo

Governor Cuomo has established some of the most ambitious energy and climate goals in the country, as are outlined in this section. In response to the US government withdrawing from the Paris Climate Agreement, a select handful of states decided to proactively form an alliance to uphold the original goals of the agreement to reduce GHG emissions. New York, along with California and Washington, have committed to the original US goal of reducing emissions 26-28 percent from 2005 levels. Together, these three states make up 10 percent of the entire country's GHG emissions (Governor's Press Office, 2017b).

In the following sections, a summary of each of the Governor's Initiatives shown on the left side of figure 3 is presented along with the connection each initiative has to AD, and how these connections can be expanded upon, where appropriate.

1.1 Methane Reduction Plan

How does AD fit in the Methane Plan?

Target: Reduce GHG emissions 40% from 1990 levels. However, the manure management sector increased from 14 percent (0.8 MMTCO₂e) of total agricultural emissions in 1990 and accounts for an estimated 19 percent (1.2 MMTCO₂e) of total agricultural GHG emissions in 2014 (NYSERDA, 2014).

ADS operated with an emphasis on GHG control can reduce CO₂e by 2.94 MT/cow annually which could have been 120,000 MT CO₂e in 2016.

In 1990, the total GHG emissions for the State, across all sectors, was 235.84 MMTCO₂e

A manure-based ADS reduces GHG emissions by 1) capturing and combusting methane to transform it into benign CO₂, and 2) displacing fossil-fuel based electricity

New York's Governor Andrew Cuomo has implemented one of the most ambitious GHG reduction targets in the country – to reduce GHG emissions by **40%** by 2030 and 80% reduction by 2050, as compared with 1990 emissions levels³. The Methane Reduction Plan was announced in May 2017. As stated in the plan: *Methane reduction is a key piece of New York's policies to address the risks from climate change. The plan will lower methane emissions, establish more robust monitoring methods so that methane sources can be fully documented, increase support and knowledge sharing among agencies and partners, and seek stakeholder involvement to enhance current regulatory and funding programs (New York State, 2017).*

Initially, efforts were focused on reducing carbon dioxide (CO₂), which by quantity is the most predominant GHG gas, however, it is far from the most potent. Between 2000 and 2014, GHG reduction efforts focused on reducing CO₂ resulted in an 18.6% reduction of CO₂ (New York State, 2017). More recently, attention has shifted to focus on reducing methane gas emissions, which by volume is much smaller, but has a 34 times higher GWP on a 100-year scale (EPA, 2017a). Methane represents 9% of the State's GHG emissions, which mostly come from three sectors: landfills, oil and gas, and agriculture (New York State, 2017).

The Plan highlights that agricultural emissions contribute 22% to the total methane emissions in the State, or about 2% of total GHG emissions statewide, and the bulk of these emissions originate from enteric fermentation and manure management, respectively (New York State, 2017). The Plan calls out the following actions as the most impactful for decreasing agriculture's methane emissions: soil carbon sequestration, diverting organics from landfills, nitrogen management and methane destruction. The effort surrounding agricultural methane destruction is almost entirely met by installation of anaerobic digestion systems (ADS) on-farm. In fact, the 28 ADS installed 1998 – 2016 have had an overall impact of reducing 120,000 MTCO₂e annually (based on 2016 values). In using the EPA's "social cost of carbon"⁴ to determine the unrealized income stream that these systems could have had, we arrive at

³ In 1990, the total GHG emissions for the State, across all sectors, was 235.84 MMTCO₂e (NYSERDA, 2017a)

⁴ The USEPA three-year (2017-2020) average social cost of carbon is \$47.82/ MTCO₂e (Wright & Gooch, 2017)

Farm-based ADs are well suited to collaborate in the diversion of organic waste from a landfill because:

- AD is the only solution that actually captures and destroys methane GHG. By combusting methane (GWP of 34) to carbon dioxide (GWP of 1) AD reduces the GWP by 34 times.
- Manure acts as a buffering material to stabilize the process, allowing for higher amounts of waste to be easily processed by AD.

Dairy cows in NY will continue to be concentrated on a fewer number of larger sized farms with nutrient management plans, thus, a higher percentage of manure will be stored long-term in anaerobic environments. Thus, it is vital to support farm-based ADs now, to be ready to capture and destroy the resulting methane.

NYS agencies participating: DEC, DPS, DAM, SWCC, NYSERDA and each recognize the value of AD in reducing methane emissions.

The full plan can be found at: www.dec.ny.gov/docs/administrative_pdf/mrpfinal.pdf

a value of over \$5 million annually (Wright & Gooch, 2017). This means that if the benefits conveyed to society by treating manure in these 28 ADS were monetized, the economics of farm ADS would be entirely different – and each system would end up on average with a little over \$200,000 per year, which could cover, for example, system O&M.

As the population of dairy cows in NY continues to be concentrated on a fewer number of larger sized farms, and as the State continues to implement measures to protect surface and ground water resources, the trends in manure management are shifting towards a higher percentage of manure being stored long-term (6 months or more). Research shows that this trend will lead to additional manure-management related GHGs, namely methane (Wightman & Woodbury, 2016). Thus, it is vital to support farm-based efforts to capture and destroy the resulting methane that will otherwise be emitted to the environment.

These efforts are contrasted with the U.S. EPA recently dropping its efforts to comply with methane pollution reduction measures enacted (New York State, 2017). As a technology that is based on the concept of capturing methane and beneficially combusting/utilizing it, anaerobic digestion is poised to make significant contributions to the overall reduction of the State's methane emissions.

Efforts for the methane reduction plan also targeted emissions from the other top two methane producing sectors. Since the efforts for the oil and gas sector do not overlap or relate to agriculture or AD technology, they are not discussed here. The landfill sector contributes about 58% to the total methane emissions in the State, which equates to 5% of overall State GHG emissions (NYSERDA, 2017a). The major effort for reducing emissions in this sector, is the diversion of organic waste from a landfill environment. Farm-based ADs in the State are well suited to collaborate in this venture for two reasons:

- 1) AD is the only solution that actually captures and destroys the resulting GHGs; composting for example, is an excellent BMP for water quality protection, however, there is both nitrous oxide and methane emissions (IPCC 2006) released to the atmosphere during organic matter decomposition.

The 28 ADS installed 1998-2016 have an overall current annual impact of reducing almost 120,000 MTCO₂e per year. The unrealized return on investment for these systems is now over \$5 million per year.

There is tremendous potential for future growth in ADS based on-farms in NYS; if the manure from half the milking cows in the State was to be treated by anaerobic digesters, more than 1,000,000 tons of CO₂e would be reduced each year.

If food and beverage entities in the State diverted their waste to farm digesters, an additional 2.28 billion ft³/year of methane could be produced, captured, and used to generate 688 million kWh of electricity, and reduce at least 512,000 tons CO₂e emissions (NYSERDA, 2009).

2) When the landfill diversions of food processing waste and municipal fraction of organic solid waste is incorporated to an anaerobic digestion system, the presence of a buffering material (such as dairy manure) stabilizes the process, and reduces system disruption which can result due to the highly variable nature of organic food waste.

The Energy Plan states that the Clean Energy Fund (managed by NYSERDA) will help to align various State programs that will support anaerobic digesters on farms, and other sites such as wastewater treatment plants, to accept diverted organic wastes.

One source of organic waste potential is represented by food and beverage manufacturers, and of the approximately 128 of these entities in the State, it is estimated that 3.8 billion ft³/year of biogas could be produced – with translates to 2.28 billion ft³/year of methane equivalent (NYSERDA, 2009). At this point in time, farms are allowed to import organic wastes up to 50% (by weight) of the manure produced on-farm, in order to incorporate into the on-farm AD process. Not only are the resulting methane emissions captured, they have the potential to be combusted in a combined heat and power (CHP) system to produce renewable energy, and further offset fossil fuel-based electricity emissions and reduced to CO₂ during combustion.

In order to examine the effects of future AD installations on GHG reductions,

Table 3 projects the estimated AD installations in 2025 and 2030, along with the GHG emissions avoided, which, for 2030, are projected to be 1.07 MMTCO₂e based on 229 farm-based ADs in the State.

Table 3. Potential CO₂e removed compared to the 2014 estimated CO₂e amounts of manure-based GHG emissions

Year	Number of NYS Dairy Farms with a Digester	Total Number of NYS Dairy Cows Feeding Digesters	Manure-Based GHG Destroyed (Percent)¹	GHG Emissions Avoided (MMTCO₂e /yr.)	Annual Value (\$Million/yr.)²
2017	28	41,000	10	0.12	5.7
2025	156	301,000	74	0.885	42.3
2030	229	364,000	89	1.070	51.2

¹Based on 2.94 MTCO₂e per cow per year (Wright & Gooch) divided by the estimated 2014 NYS manure management GHG emissions (NYSERDA, 2017a)

²Based on \$47.82/Metric Ton as the average price for 2017-2019 (EPA, 2017b)

1.2 New York State Energy Plans: Reforming the Energy Vision (REV) and the Clean Energy Standard (CES)

How Does AD Contribute to REV?

The REV calls for a 40% reduction in greenhouse gas emissions as compared with 1990 levels

AD capture and combustion of methane reduces the GWP by 34 times and has three times the GHG reduction per kWh as wind or solar.

Goal: 50% of the total electricity generation from renewable energy sources by 2030

AD has a high capacity factor so can be relied upon for baseline renewable energy, regardless of environmental conditions. Biogas can be stored for later use when the value is maximized, or when other technologies are operating at a low CF.

The 2015 New York State Energy Plan is a comprehensive roadmap to build a clean, resilient, and affordable energy system for all New Yorkers and should include AD.

These New York State Energy Plans (referred to herein as the Energy Plan) outlines several initiatives that have been set in motion in the State to stimulate various aspects of sustainable and affordable energy production. The Energy Plan recognizes that the energy system we currently have in place is antiquated, and not adequately designed to meet the growing needs of citizens, businesses and farms across the State. A change in the sourcing and distribution of energy is sorely needed to be able to advance different growing sectors of New York's economy. In the execution of the Energy Plan, NYSEDA, NYPA, NYDEC and other relevant State agencies will provide feasible access to resources and assistance to enable the development of clean energy solutions for communities. Municipalities and communities across the State will be able to employ these solutions to provide electricity, heating, water, land use and transportation systems.

The Energy Plan describes the State's clean energy future as "...affordable, reliable, resilient, and dynamic". Anaerobic digestion technology can successfully assist in meeting these future goals in the following ways:

- **Affordable:** As newer and more efficient distributed energy resources, such as manure-based AD are brought online, older energy generation units are becoming less efficient and less economically viable to compete against new resources (NYISO, 2017). AD has a high electric energy output per unit of investment compared to other renewable energy sources as shown in the adjusted capital costs in **Table 2**. AD can provide electric output uniformly and continuously without additional storage costs that wind and solar might have. However, if appropriate, biogas could be stored to meet peak demands when needed.
- **Reliable:** AD can provide a consistent back-up to traditional renewable energy systems when wind and sunshine are minimal. Dairy cows provide a continuous supply of raw material to produce the biogas for electric output. The capacity factor for AD is higher than wind and solar renewable energy and can be managed to maintain production despite the weather.

Total manure management related methane emissions in 2014 were 0.79 million metric tons CO₂e, a 37% increase from 1990 levels.

Manure management accounted for 19% of total ag-related emissions in 2014.

An ADS reduces GHG emissions by 1) capturing and combusting methane to transform it into net neutral CO₂, and 2) displacing fossil-fuel based electricity used on-farm.

An ADS in NY yields an average GHG emission reduction of 2.94 MTCO₂e/cow-year, or 3.23 tons of CO₂e/cow-year

There is tremendous potential for future growth in ADS based on-farms in NYS; if the manure from half the milking cows in the State was to be treated by anaerobic digesters, 1,040,760 tons of CO₂e would be reduced.

The REV plan promotes the idea of developing ‘community microgrids’ which would incorporate locally generated clean energy, including from the 28 ADS in operation across the rural areas of the State.

NYS agencies participating: NYSDA, NYPA, DEC, DPS etc.; each recognizes the value of AD in providing renewable, distributed, constant, electricity.

- *Resilient:* AD technology can accommodate various additional feedstocks and substrates at different loading rates. The microbial community at steady state can handle atypical situations calling for the stabilization of outside organic materials, converting them into energy and a benign effluent useful as a fertilizer. AD is not simply an energy generation technology; it provides benefits across many levels of rural community life, and when employed by farms, empowers rural areas to access clean, distributed energy, while enjoying other benefits to water quality, job creation, land use, and other. On-farm AD can extend the life of landfills, while reducing their GHG emissions by diverting organic waste to be recycled into energy and nutrients.

- *Dynamic:* AD output can be moderated to meet energy needs on-farm or as the grid demands with a biogas storage. There is no “silver bullet” that will ensure our transition to a clean energy future; AD is a part of the diverse make-up of electricity sources, making the energy system more secure and reliable.

The Energy Plan targets are to:

- 1) **Achieve a 40% reduction in greenhouse gas (GHG) emissions as compared with 1990 levels**
- 2) **Supply 50% of the total electricity generation from renewable energy sources by 2030**
- 3) **Increase the statewide energy efficiency by 23% (by 600 Trillion Btu).**

The first two energy targets are discussed in detail below, as they relate to AD. Following the energy goal discussion, other points of the plan that relate to AD are discussed, including how farm-based AD can help to advance each goal defined by the Energy Plan.

40% reduction in GHG emissions

Reducing GHG emissions from all sectors—namely, power generation, agriculture, and transportation—is critical to protecting the health and welfare of New Yorkers both now and in the future. NYS has one of the country’s most ambitious plans to reduce its GHG emissions. One of the principal objectives of the *Renewable Energy Vision* is to reduce GHG emissions and other pollutants in order to protect public health and welfare (NYS Energy Planning Board, 2015a).

The 2027 statewide forecasted annual energy usage is 155,000 GWh, a 23% decrease from current usage.

Currently, operational ADS in the State are producing 13.1 MW of electricity.

If the manure from half the milking cows in the State was to be treated by anaerobic digesters, 528,000-MWh of electricity could be generated annually.

If food and beverage entities in the State diverted their waste to farm digesters, 702,000-MWh of renewable electricity could be produced annually

The NYS population in 2005 was almost 19.5 million, and is expected to grow to 20.5 million by 2030

The Energy Plan seeks to update the utility business model, which will support the inclusion of renewable energy generation; AD stands to conquer one of the largest barriers to widespread adoption.

In 1990, the total GHG emissions for the State, across all sectors, was 235.84 MMTCO₂e (NYSERDA, 2017a). Specific to agriculture sources, the levels of methane emissions from manure management increased from 0.5 million tons of CO₂e to 0.79 million tons of CO₂e in 2014. The total manure management GHG emissions were almost 1.2 million tons CO₂e in 2014 (NYSERDA, 2017a). The increase in emissions related to manure management over the 24-year span is correlated to an increase in the quantity of manure stored long-term over that same period. Although manure storage is a commonly implemented and recognized Best Management Practice (BMP) that addresses water quality concerns, long-term manure storage creates GHG emissions, primarily from methane (CH₄) in anaerobic conditions but also nitrous oxide (N₂O) in aerobic conditions.

As mentioned, an ADS can effectively reduce GHG emissions by 1) enhancing methane production and then collecting and combusting it. This reduces the methane that is then generated in manure storages. The methane is transformed into CO₂, which has a much lower GWP and 2) displacing fossil-fuel based electricity used on-farm. Using average values for baseline and obtainable values for AD conditions, it was calculated that an ADS in NY could yield an obtainable GHG emission reduction of 2.94 MTCO₂e/lactating cow-year (Wright & Gooch, 2017). Using this value, an annual depiction of the combined potential annual GHG emission reductions by installed ADS was developed and is shown in **Figure 5**.

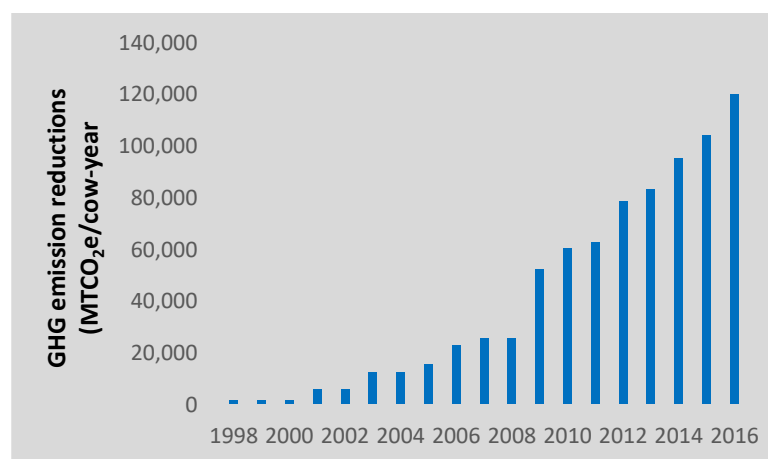


Figure 5. Potential annual GHG emission reductions from existing ADS in NY by year

The 28 ADS installed 1998-2016 could have an impact of reducing 120,000 MTCO₂e of GHG emissions per year. Despite the fact that this overall reduction may appear insignificant when compared with total ag-related GHG emissions, manure management accounted for 14% and 19% of total ag-related

The resources which a farm-based AD can provide for the community include:

<i>Heat</i>	<i>Electricity</i>
<i>Fertilizer</i>	<i>Nutritious dairy</i>

The many positive social interactions are also evident –

<i>Stable job creation</i>	<i>Responsible land-use</i>
<i>Protection of water quality</i>	<i>GHG emissions reduction</i>

The ability to integrate an AD system to receive waste products from the community makes the farm an effective circular system that recycles wastes to produce beneficial resources.

Renewable natural gas (RNG), or biomethane, is refined biogas, and can be used in alternative fuel vehicles employing natural gas as a fuel, as it is fully interchangeable with conventional natural gas.

There are 2 dairy farms in the country that use RNG to produce transportation fuel, and subsequently use it to power milk trucking fleets.

The use of the RNG powered milk trucking fleet reduces their lifecycle GHG emissions by 80%.

Anaerobic digestion pursued on-farm can reduce organic wastes, including residential food scraps, and industrial food waste, that otherwise would decompose in landfills, releasing GHGs, mainly methane.

emissions in 1990 and 2014, respectively (NYSERDA, 2017a). So there is opportunity for a relatively significant impact to be made by AD technology, in terms of GHG reduction.

There is tremendous potential for future growth in farm-based ADS in NYS. The prior version of the NYS energy plan (2009) calculated that New York's farms have the potential to produce 6 trillion Btu of energy from anaerobic digester systems annually. Based on an average biogas yield of 80 ft³/cow-day (Gooch et al., 2011) from digesters fed manure only, our calculation shows this represents the digestion of 354,000 milking cows, only about half the current population of milking cows in the State. If the manure from these milking cows was to be treated by anaerobic digesters, an estimated 1,040,760 MTCO₂e would be reduced (Wright & Gooch, 2017). When including the potential for co-digestion of organic wastes, this number is much higher. As mentioned previously, if food and beverage entities in the State diverted their waste to farm digesters, an additional 2.28 billion ft³/year of methane could be produced (New York State, 2009), captured, and used to generate 240 million kWh of electricity, and reduce at least 146,000 MTCO₂e emissions.

Supply 50% renewable energy by 2030

This goal, also known as the Clean Energy Standard (CES), is the cornerstone target of the overarching REV plan. While there is currently a strong push for increasing the solar generation capacity across the state, an overall diversity in renewable energy generation, including solar, wind, hydropower and biomass, will be vital to ensure an adequate energy supply, to reduce GHG emissions and to stabilize electricity price volatility.

The energy plan also aims to improve the access and affordability of electricity to NYS customers, and to reduce energy bills for business. The REV includes private capital investment as a strategy to encourage cost-effective, clean distributed energy resources. Individual farms have invested in AD technology and are willing to continue if there is an economic reason to do so. The energy plan states, "Renewable distributed generation resources will also help protect customers from unpredictable swings in energy prices by reducing dependence on fuels that have volatile prices" (NYS Energy Planning Board, 2015a). AD technology is a prime candidate that meets the goal of providing a consistent energy price while expanding the energy generation portfolio, and that could greatly benefit from private capital investment, as these systems require large amounts of capital to install and start up.

In line with facilitating access and lowering prices of electricity across the State, the reliability and resiliency of the grid is equally as important, as is spelled out in the energy plan. Longer power outages result in greater economic impacts to customers and businesses, and they are on the rise across the country (NYS Energy Planning Board, 2015a). The REV promotes the idea of developing ‘community microgrids’ which would incorporate locally generated clean energy, including that from the existing 28 ADS in operation and the potential future AD systems, across the rural areas of the State. Dairy farms in specific locations that would benefit most from a distributed power supply should be encouraged to participate with an AD. A community microgrid has the ability to maintain electricity supply at critical facilities when the main power grid fails, and to offer a cost-effective complement to the central grid at all other times or normal operation.

Figure 6 shows NYS cumulative customer-sited renewable energy generation capacity for 2001 through 2011 (NYS Energy Planning Board, 2015b).

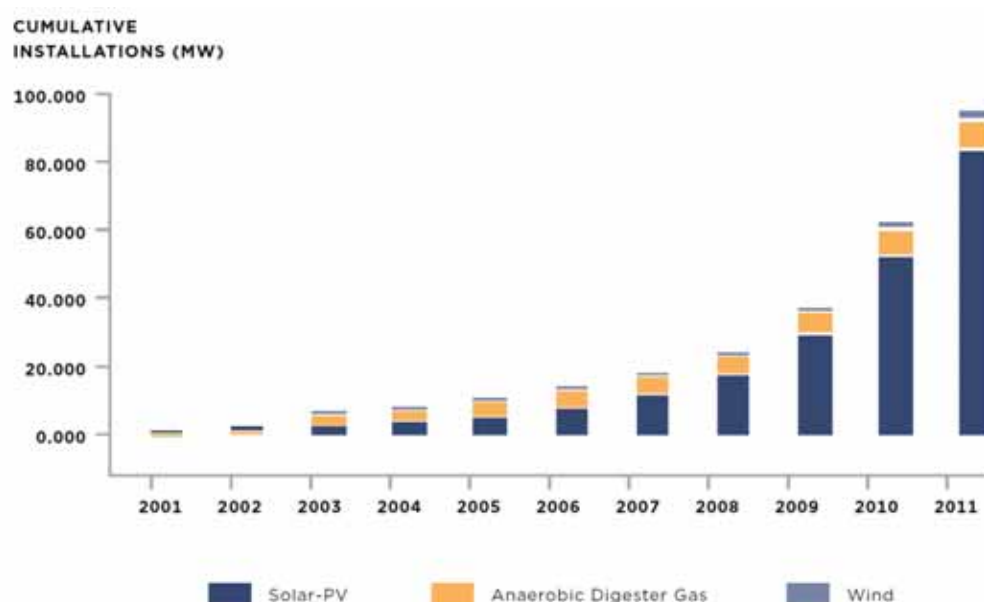


Figure 6. Cumulative Customer-Sited Renewable Energy Capacity (2001-2011) AD gas includes municipal waste AD (NYS Energy Planning Board, 2015b)

Anaerobic digestion technology and distributed generation

This sub-heading was added to provide some more basic information on the process of generating renewable energy from anaerobic digestion technology, current generation capacity, and future energy needs in the State.

A significant part of the energy plan is to transform the existing grid from a few centralized sources of energy, to a distributed grid where energy is generated from many sources. The renewable electricity generated from manure-based biogas, is conveyed to the central electricity grid, and is referred to as locally produced, clean distributed energy. Looking to the future, AD technology is positioned as a meaningful player in the diverse portfolio of distributed generation sources for New York State. Currently, operational ADS in the State have a generation capacity of 13.1 MW of electricity (see **Figure 9** in Appendix B); some of the energy generated is used on-farm to offset fossil-fuel originated electricity purchased from the grid, while the remainder is conveyed to the central power grid. Distributed generation would require a variety of renewable sources to provide electricity during both peak and off peak hours. Only 28 on-

farm AD installations are currently in operation, but the potential for using AD technology to generate significantly more distributed renewable energy is very probable.

In addition to farm-based biomass used for biogas production, New York's 128 active food and beverage manufacturing facilities have an estimated biogas producing potential of 3.9 billion cubic feet per year, or approximately 2.1 trillion Btu per year (New York State, 2009). Therefore, the previous version of the NYSEP states that a conservative estimate for New York's total biogas production potential is approximately 8 trillion Btu. Our analysis shows this potential translates to 702,000-MWh annually.

The energy plan used a *bounded technical potential* method⁵ to assess the future potential of generation from renewable sources. Not considering cost or future technology advancements, the plan estimates approximately 69% of the energy usage in NYS could be fulfilled using in-state renewable resources (NYS Energy Planning Board, 2015b). **Table 4** (NYS Energy Planning Board, 2015b) shows the technical potential of each renewable resource and the percentage that resource could fulfill of the State's overall energy usage. The bioenergy category includes: (1) forestry- and agriculture-based sources of non-fossil plant materials that could be processed into various energy products; and (2) methane produced from the anaerobic decomposition of biogenic material from sources such as landfills, wastewater treatment plants, manure, and other agricultural byproducts, and food processing facilities.

Table 4. Preliminary New York Renewable Energy Bounded Technical Potential Electricity Generation (GWh)¹

RESOURCE	IN-STATE GENERATION (GWh) (2011)	STATEWIDE ELECTRICITY DEMAND (%) (2011)	PROJECTED IN-STATE GENERATION (GWh) (2020)	PROJECTED STATEWIDE ELECTRICITY DEMAND (%) (2020)	PROJECTED IN-STATE GENERATION (GWh) (2030)	PROJECTED STATEWIDE ELECTRICITY DEMAND (%) (2030)
Hydro	27,634	17%	27,858	16%	37,395	20%
Bioenergy	945	0.6%	2,473	1.4%	5,418	2.9%
Wind	2,828	2%	9,844	5.7%	32,906	18%
Solar	7	0.00%	18,919	11%	54,316	29%
TOTAL	31,413	19%	59,094	34%	130,035	69%

¹Source: NYS Energy Planning Board, 2015b

Notes: Bioenergy includes: (1) forestry- and agriculture-based sources of non-fossil plant materials that could be processed into various energy products; and (2) methane produced from the anaerobic decomposition of biogenic material from sources such as landfills, wastewater treatment plants, manure, and other agricultural byproducts, and food processing facilities.

As the population of New York State is expected to increase in the coming decades, it is imperative to plan how the increased numbers of residents are going to impact the energy sector – and where that demand difference will occur, either in rural or urban areas. Equally important, is to recognize the increased need for food for these additional residents, which could ultimately affect dairy cow population, and accordingly, manure stored long-term, which could mean increased GHG emissions (namely methane). It is important to have technologies in place now to control GHG emissions, in order to be prepared to responsibly manage the increase in emissions that is likely, based on demographic trends.

⁵ As explained in the energy report...“pure” technical potential offers little guidance to policy makers since it does not present a practical assessment of resource use. In contrast, the bounded technical potential (BTP) for a given resource is an estimate of the total available thermal or electric energy based on consideration of the primary physical, social, and technological factors at play (New York State Energy Planning Board, 2015b).

According to current demographic projections, the NYS population in 2005 was almost 19.5 million, and is expected to grow to 20.5 million by 2030, as shown in **Figure 7** (Brown & Blakely, 2011).

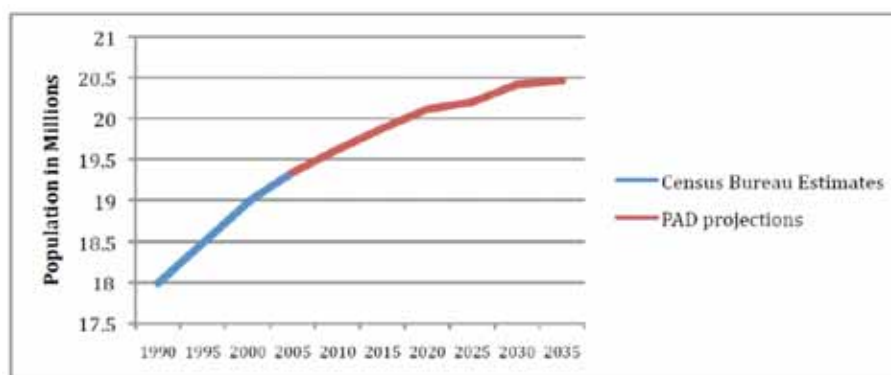


Figure 7. NYS population estimate and projection (1990 - 2035) (Brown & Blakely, 2011)

While the metropolitan region downstate will see increases based on internal and external migration, upstate areas will see an overall decline in population (Brown & Blakely, 2011). This means that in providing energy to the increased population, this plan *must* account for enhancements and upgrades to existing distribution systems to carry renewable distributed energy resources to the population centers.

Increase statewide energy efficiency by 600 trillion Btu

It is very clear that despite how much we increase the supply of renewable electricity in the State, it will always be necessary to first, responsibly manage our electricity usage, constantly striving to reduce our impact; this is where energy efficiency comes in to play. The reduction goal of 600 trillion Btu is equivalent to a 23% reduction in 2012 energy consumption in buildings (NYS Energy Planning Board, 2015a). This value is equivalent to 176 billion kWh.

New York State dairy farmers have been regular adopters of new technology to decrease energy usage. Some examples of recent advancements are: variable frequency drive vacuum pumps and milk pumps, energy efficient ventilation and cooling fans, HPS lighting and more recently LED lighting. When a farm utilizing AD technology to produce on-farm electricity increases energy efficiency, more of the power generated can be sent to the central power grid, rather than using it to meet energy demands on the farm.

Modernizing the Utility Business Model

The energy plan targets the idea of updating the utility business model. The energy plan calls out concern for the fact that utility companies in NY do not operate with a business model that allows for integration into a future more based on distributed energy generation. Utility companies need to have an incentive to adapt to and accommodate a greater diversity of distributed energy resources, such as manure-based AD. The plan strategizes that policies should “enable utilities to earn returns by advancing markets in energy efficiency and distributed energy resources, and in so doing, transition clean energy from the periphery to the core of the utility business model” (NYS Energy Planning Board, 2015a).

The traditional model that most utilities follow – reliance on large central generation sites for widespread distribution, is apparent when investigating one of the common challenges to AD-based

electricity generation. One challenge that has been encountered repeatedly, is that many of the farms that have installed an ADS have had difficulties working with the utility to interconnect with the grid to be able to sell excess electrical energy generated. In 2010, a farmer survey (Gooch and Pronto, 2009) found that the following issues were of concern to farms considering installing an ADS, based on the fact they were experienced so frequently by farmers seeking to increase their portion of renewable distributed electricity sent to the grid:

- excessive delays in determining line upgrades
- exorbitant cost estimates to upgrade lines
- poor cooperation or understanding by utilities.

With the support of The NY Department of Public Service working to support the Energy Plan including Working Groups that may seek to change such behaviors to better support the inclusion of renewable energy generation, AD may stand to conquer one of the largest barriers to widespread adoption.

Sustainable and Resilient Communities

As the customer remains one of the focal points of the energy plan, supporting more sustainable local energy systems will help to revitalize communities by improving access to affordable energy, creating jobs and stimulating environmental improvements. The energy plan places emphasis on improving the affordability, specifically, for low-to-middle income customers, which is a goal in harmony with that of increasing distributed generation resources across the same areas. Diversifying distributed energy sources will assist with grid reliability, and in meeting the State's clean energy targets. Anaerobic digestion technology fits perfectly with these goals, not only as a locally-produced renewable distributed energy resource, but because of the multitude of additional benefits to society and the environment, that this technology offers.

In 2010, one of the largest gatherings of dairy-farm based AD technology stakeholders took place, and one of the results was the unified community vision shown in **Figure 4**, centered on a dairy farm employing anaerobic digestion to treat manure and to create renewable energy. The illustration shows the farm and AD system providing several resources for the community – heat, electricity, fertilizer product, and of course, nutritious dairy products. The many positive social interactions are also evident – reduction of GHG emissions, stable job creation, responsible land-use and protection of water quality. Lastly, the ability to integrate the AD system to also receive waste products from the community makes the farm an effective circular system that recycles wastes to produce beneficial resources.

The NY Prize “Opportunity Zone Map” has made public the approximate geographic areas that have been identified by local electric distribution companies as locations where microgrids and distributed energy resources may reduce utility system constraints and defer expensive infrastructure investment costs. Community microgrid infrastructure will serve as a foundation for REV objectives, helping communities reduce energy costs, promote clean energy, and build reliability into the electric grid (NYS Energy Planning Board, 2015a).

Transportation

The use of petroleum in the transportation sector continues to be a significant source of air pollution in New York, exacerbating problems with ozone, particulate matter, and benzene, cites the

energy plan. In addition, the transportation sector accounts for more than one-third of the State's GHG emissions. New Yorkers spend more than \$20 billion each year on gasoline and diesel fuel imported from out-of-state (NYS Energy Planning Board, 2015a). In line with reducing GHG emissions while increasing reliable, clean fuels sourced in-state, AD technology offers an effective solution for the transportation industry, both in personal vehicle as well as commercial trucks.

The energy plan will reduce petroleum use and associated emissions from the transportation sector through several strategies, including investing in more energy efficient ways to move people and freight; and making strategic investments in transit infrastructure, among others (NYS Energy Planning Board, 2015a). One initiative to reduce GHG emissions from the transportation sector will be the pursuit of sustainable fuel production. Directly from the energy plan,

"...the Department of Agriculture and Markets, NYSEDA, and DEC will develop a comprehensive, cost-effective strategy to support in-State, sustainable, low-carbon fuel production using agricultural and organic waste feedstock, especially as a substitute for petroleum fuels imported from out-of-state (NYS Energy Planning Board, 2015a)."

Despite the apparent focus on mainly plug-in hybrid vehicles, compressed natural gas vehicles are listed as *Clean Fleet Program* approved vehicles (NYS Energy Planning Board, 2015a). The agencies' initial focus will be on developing strategies to support the use of organic waste to produce liquid and gaseous bioenergy products (NYS Energy Planning Board, 2015a). On-farm AD technology perfectly fits with this initiative, as most of the feedstock to produce the proposed biofuels would originate on farm, and while these wastes, such as manure, contain mostly water, it makes economic sense *not* to move these materials to another site for fuel production.

Dairy manure-based renewable natural gas (RNG), or biomethane, can be used in alternative fuel vehicles employing natural gas as a fuel, as it is fully interchangeable with conventional natural gas. Biogas refined to RNG for vehicle use undergoes a process which removes water vapor, carbon dioxide, hydrogen sulfide, and other trace elements. The resulting RNG has a higher methane content than raw biogas, which makes it virtually equivalent to conventional natural gas and thus a suitable energy source in applications that require pipeline-quality gas. Like conventional natural gas, RNG can be used as a transportation fuel in the form of compressed natural gas (CNG) or liquefied natural gas (LNG). RNG qualifies as an advanced biofuel under the Renewable Fuel Standard (AFDC, 2017). Hilarides Dairy in California and Fair Oaks Dairy in Indiana are using RNG to produce transportation fuel, and using it to power milk trucking fleets.

Fair Oaks Dairy Farm in Indiana uses an on-farm anaerobic digester to produce biogas, which is then refined to RNG, and piped to one of two CNG filling stations in the area. The farm and its' associated trucking company, partnered with the Indiana "Clean Cities" coalition and used federal Recover Act funding to increase the alternative fuel usage in the state. Other goals of the project were to reduce trucking fuel costs and similarly, to reduce trucking-related GHG emissions from the standard use of diesel fuel. The trucking company committed to the project by converting the entire 42-truck fleet of semi-tractors to run on CNG, in turn creating one of the largest fleets of Class 8 trucks run on natural gas (US DOE, 2013). The dairy products produced by the farm are distributed to various points-of-sale across the country, all with the use of the RNG powered trucking fleet, which reduces the lifecycle GHG emissions by 80% (US DOE, 2013). This same type of system could be utilized in NYS. Two trucks from the farm's fleet are shown re-filling at one of the CNG stations where biomethane from the ADS is piped (**Figure 8**).



Figure 8. Fair Oaks trucking fleet at their CNG filling station in Indiana (Kowitt, 2016).

Since there are so many additional environmental and social benefits attributable to AD technology, RNG produced from these systems remains a logical solution for the transportation sector.

Organic Waste Management

Another area of focus for the energy plan is the responsible management of organic waste. The reach of initiatives under this area of the plan apply to water treatment plants, farms and residents and communities in general. The energy plan suggests targeting opportunities such as: reducing operating costs at wastewater treatment plants, introducing new revenue streams at farms, and developing community-based energy sources.

NYSERDA and DEC will work with “private partners, regulators, and stakeholders representing the agricultural, food processing, and source separated food-waste management sectors to develop and spur market adoption of innovative and replicable solutions, including anaerobic digester biogas production and use, to deliver operational and energy productivity gains, and additional revenue streams (NYS Energy Planning Board, 2015a).”

Anaerobic digestion pursued on-farm offers a prime partnership opportunity to reduce organic wastes from other sources, including residential food scraps, and industrial food waste at a lower cost to society (NYSERDA March 2017). A higher pH buffering material, such as dairy manure, is needed to facilitate the anaerobic decomposition of higher-strength organic materials. The diversion of these wastes from otherwise being landfilled has a number of benefits, including reduction of GHGs, since the wastes will be decomposing in an environment where the methane released will be captured, combusted, and beneficially used.

There are many associated economic benefits of co-digesting off-farm food wastes with on-farm dairy manure. Normally, there is a fee paid for the farm to receive such wastes, as the entity producing the waste would otherwise need to pay for disposal of the waste, therefore creating a revenue stream for the farm. The amount of this fee is highly dependent on many factors, including: the alternative disposal options and costs, strength of the substrate, length of contract, and distance to haul. In addition, with the increase in organic waste to the ADS, all outputs otherwise realized are enhanced – biogas production and subsequent heat, electric or RNG production, and nutrient-rich effluent, either in solid or liquid forms.

1.3 Clean Climate Careers

How does AD fit into Clean Climate Careers?

Goal: Accelerate renewable energy growth with a \$1.5 billion investment in projects.

With proper funding, a skilled, trained workforce can be created to plan, design, construct, and operate farm-based ADs in the State, which would in turn enhance renewable energy production and aid in the reduction of GHG emissions.

With the inclusion of AD technology to dairy farms, the number of hired workers could be increased from the current rate of employment (20,000 people), and would include more technical and skilled positions, which are more likely to be permanent.

In June 2017, Governor Cuomo announced the Climate and Jobs Initiative in partnership with the Worker Institute at Cornell University ILR's School and Climate Jobs NY, to help create 40,000 clean energy jobs by 2020.

The initiative, being touted as the 'largest clean energy procurement by a state in US history', will significantly support renewable energy growth, with up to \$1.5 billion investment in renewable energy projects with the goal to stimulate job creation (Governor's Press Office, 2017c). If this initiative is inclusive of various types of renewable energy, farm-based anaerobic digestion (AD) stands to benefit from the influx of project development funds. AD as a technology is an extremely capital intensive endeavor, which banks are normally wary to lend in full to farmers, due to the historically poor return on investment and high rate of lost capital. Investment of project funds in AD would be ideal, as the technology has a comparatively higher return on investment due to 1) lower adjusted capital costs, and 2) comparatively higher GHG emission reduction factor, up to 3x that of competing technologies.

The implementation of an AD on a farm creates multiple new jobs for planning and design, during the construction and start-up phase, but more importantly there are multiple skilled positions created and maintained to operate the system. There are many aspects of the AD system that require a skilled, technical labor force, including the daily system monitoring and gas and effluent testing, engine generator set maintenance and repair and biogas clean-up systems.

The initiative will also invest \$15 million in workforce training programs for the clean energy industry. This would be a prime opportunity for the creation of an AD-skilled workforce to serve farms across the state, something that is currently lacking and badly needed. Investing in the training needed to design, build and operate AD systems that reduce

GHG emissions three times that of other renewable energy technologies should be a high priority. When an AD system is closely monitored and professionally managed (something that is difficult for a farm enterprise to spend money and labor on, with the marginal returns currently in place), the production of biogas and/or renewable electricity can be significantly increased. The reduction of GHGs is also enhanced, as there is less likelihood of leaks with closer management of the system.

In 2015, the dairy industry hired approximately 20,000 people in New York State (NASS). With the inclusion of AD technology to dairy farms, this number could be increased even further, and would

include both basic labor jobs as well as more technical and skilled positions, which are more likely to be permanent. During system installation and start-up there are many jobs necessary relating to construction, concrete and plumbing. Increases in traffic and people visiting these rural sites has a direct positive impact on the local economics with the stimulation of purchases at local stores and restaurants. Additionally, the concept of co-digesting off-farm organic waste at these facilities increases the scope and level of jobs created even further – to include trucking jobs, heavy machinery operators, machinery repair services, plumbers and pipe fitters, and laboratory analysis technicians. When there is potential for employment, there is an increased likelihood that local students will pursue a technical education in a related field.

1.4 Regional Economic Development Councils

How Does AD Benefit Local Economies?

An ADS can yield additional income for the farm, from the sale of the following items:

- Excess electrical energy
- Renewable energy credits
- Excess combustion heat
- Post-AD separated manure solids
- Carbon credits
- Organic fertilizer

When farms are doing well economically, the local communities are more likely to prosper.

ADS will improve the quality of life in local communities by enhancing air and water quality.

<https://regionalcouncils.ny.gov>

The Regional Economic Development Council initiative (REDC) is a key component of Governor Andrew M. Cuomo's transformative approach to State investment and economic development. In 2011, Governor Cuomo established 10 Regional Councils to develop long-term strategic plans for economic growth for their regions. The Regional Councils have redefined the way New York invests in jobs and economic growth by putting in place a community-based, bottom up approach and establishing a competitive process for State resources.

This initiative is a key component of Governor Cuomo's approach to economic development, putting into place a community-based, bottom up approach and establishing a competitive process for State resources. The 10 Regional Councils develop long-term strategic plans for economic growth in their regions. They are made up of local experts and stakeholders from business, academia, local government, and non-governmental organizations.

As is discussed in the previous section on Clean Climate Careers, there are many jobs associated with the design, construction, start-up, and on-going operation and maintenance for an AD. With this and other support systems in place to provide local resources and funding, AD implementation can be facilitated for farmers.

In many rural areas of NYS, the main employers are often agricultural entities, and more often than not, are dairy farms specifically, since this is the most significant agricultural activity in the State. An ADS can yield additional income for the farm, if the investment is designed well, and if the annual cost to own and operate the system is less than the revenue provided by the system. Potential revenues can come from the sale of the following items:

- | | |
|---------------------------------|--|
| <i>excess electrical energy</i> | <i>renewable energy credits</i> |
| <i>excess combustion heat</i> | <i>post-digested separated manure solids</i> |
| <i>carbon credits</i> | <i>organic fertilizer</i> |

When farms are doing well economically, they enhance the likelihood that the local communities will also prosper, since they hold a large portion of the rural community employment opportunities.

Additional enterprises that could have a symbiotic relationship with an on-farm AD include: Food or grain processing that could use the waste heat from the AD engine-generator set while the AD provides a recycling method for any organic wastes, greenhouses that could use both the waste heat and electricity for augmented lighting as well as the CO₂ from the AD system while also using the AD for any organic waste recycling. Lumber drying enterprises could also utilize the waste heat from the AD engine generators to dry wood. Each of these enterprises could offer economic stimulus and diversity to the rural areas of NYS.

1.5 Dairy and Yogurt Summit

What Role does AD Play in Relation to the Yogurt Industry?

Through co-digestion, AD systems meet the demand for organic byproduct management, and can accept the high-strength whey and other byproducts from the yogurt production process, and transform it into: beneficial soil amendments and renewable energy, all while reducing GHG emissions.

Monetizing the GHG reductions of ADS would increase the profitability and income diversity of dairy farms.

In 2014, the second New York State Yogurt Summit brought together industry leaders and representatives from the State government to collaborate on advancing the industry. NY was titled 'yogurt capital of the nation', and the Governor committed to continuing the resources to maintain this distinction. At the first summit held in 2012, the Governor increased the funding for anaerobic digesters to up to \$2 million per project.

The expansion of yogurt manufacturing over the past several years has further driven the need for sustainable methods to manage organic processing by-products, in order to encourage continued growth and success of the New York State food processing and milk supply industries. Governor Cuomo recognized these needs and has partnered with food processors and dairy farms to work towards solutions. Thanks to Governor Cuomo's recent support, as well as State and Congressional legislative leaders, there has been an unprecedented level of conversation and interest in growing the State's anaerobic digester industry.

Anaerobic digestion (AD) technology has been touted as a win-win solution for food processors, agriculture, the environment, and the State's citizens; at the most basic level, it converts organic matter to renewable energy. However, in order to fully realize the multitude of benefits AD technology has to offer, a collaborative effort must be made to ensure resources exist to promote viable solutions to the barriers that exist, in order to facilitate the use of AD systems to meet the demand for organic byproduct management.

1.6 Clean Energy for Agriculture Task Force

How Will the CEATF Advance AD?

ADS are a significant source of clean energy. AD not only replaces the fossil fuels with renewable energy, they also capture and combust methane to reduce GHG emissions as well as to provide a mechanism for organic waste recycling, yielding additional GHG reductions and nutrient savings.

The principle initiative to support AD technology is to identify and develop strategies to monetize the societal benefits of AD.

The full plan can be found at: <https://www.nyserda.ny.gov/About/Publications/Clean-Energy-for-Agriculture-Task-Force->

As a result of industry feedback at the Yogurt and Dairy Summit, the Renewable Energy for Agriculture Task Force was formed in order to apprise the Governor on renewable energy opportunities and industry-specific needs. The Task Force is comprised of State and industry representatives, and NYSERDA has been the leading driver.

The Clean Energy for Agriculture Task Force—an assembly of farmers, universities, agriculture organizations, and others—is helping identify and prioritize clean energy opportunities for New York State’s agriculture sector. The resulting Clean Energy for Agriculture Task Force Strategic Plan identifies initiatives to cut energy costs and accelerate the use of clean energy by the more than 35,000 farms across the State. Led by NYSERDA and New York State Department of Agriculture and Markets, the Task Force members will follow up to ensure the implementation of action steps identified in the plan.

Collectively, sub-groups of the task force identified 20 initiatives from over 80 possible initiatives presented to them. Below are listed the AD-related initiatives in the Plan (NYSERDA, 2017b).

- (3.1) Expand renewable energy in the agriculture sector (including AD)
- (3.3) Identify and develop strategies to monetize benefits
- (3.4) Increase transparency in renewable energy pricing
- (4.1) Provide information and coaching for existing and prospective AD projects through the ongoing Cornell AD Assistance Initiative (ADAI)
- (4.2) Provide funding for market development analysis to advance AD project implementation
- (4.3) Provide cost-sharing for development and evaluation of new AD business models
- (4.4) Consider impacts on AD of potential legislative, regulatory, tariff, and program changes

Work will continue over two years implementing initiatives and incorporating new strategies.

Section 2. NYS Agencies with Programs relevant to AD

In the following sections, a summary of each of the New York State Agencies with programs relevant to anaerobic digestion shown on the right side of figure 3 is presented along with the connection each initiative has to AD, and how these connections can be expanded upon, where appropriate.

2.1 NYSERDA



How Does NYSERDA Support AD?

The CEF would provide \$5 billion in new strategic investment in the statewide clean energy economy over 10 years, starting in 2016.

Farm-based AD is a proven technology that has been in use for decades, however, it is not a mature industry in NY. NYSERDA recognizes that much work is needed to overcome the barriers that exist, and to develop the potential markets and revenue generation possibilities.

Aggregation of farms, financing, designs, construction and operation to improve economies of scale are being considered.

Clean energy can power New York while protecting the environment. The New York State Energy Research and Development Authority, known as NYSERDA, promotes energy efficiency and the use of renewable energy sources. These efforts are key to developing a less polluting and more reliable and affordable energy system for all New Yorkers. Collectively, NYSERDA's efforts aim to reduce greenhouse gas emissions, accelerate economic growth, and reduce customer energy bills.

The Clean Energy Fund

The Clean Energy Fund complements the REV Regulatory Docket to reinforce New York State's commitment to accelerate the growth of clean energy; improve its economic competitiveness; and protect the environment by reshaping the State's energy efficiency, distributed renewable energy, and energy innovation programs to reflect a common objective. The CEF would provide \$5 billion in new strategic investment in the statewide clean energy economy over 10 years, starting in 2016. The CEF will serve as the primary funding vehicle for NYSERDA's ongoing and future initiatives.

The CEF will pursue three long-term outcomes: (a) new market opportunities to attract private capital to invest in clean energy in New York; (b) greater deployment and maturity of clean energy technologies and industries; and (c) significant reductions in GHG emissions.

Farm-based AD is a proven technology that has been in use for decades, however, it is not a mature industry in NY. Much work is needed to overcome the barriers that exist, and to develop the potential markets and revenue generation possibilities that exist. In addition, resources are needed to forge synergistic partnerships with entities such as greenhouses, transportation, nutrients, and other value added products.

2.2 Department of Environmental Conservation



How Does DEC Support AD?

ADS is recognized as an agricultural best management practice (BMP) and as a way to reduce GHG.

Mitigating the impact of climate change depends on reducing GHG emissions; ADS can reduce GHG emissions by 2.94 metric tons per cow-year, while providing renewable energy.

While manure storage is being promoted as a water quality BMP, it is causing an increase in GHG emissions. ADS implementation can reduce this impact if designed into the manure management system on a dairy farm.

"To conserve, improve and protect New York's natural resources and environment and to prevent, abate and control water, land and air pollution, in order to enhance the health, safety and welfare of the people of the state and their overall economic and social well-being."

DEC's goal is to achieve this mission through the simultaneous pursuit of environmental quality, public health, economic prosperity and social well-being, including environmental justice and the empowerment of individuals to participate in environmental decisions that affect their lives.

Office of Climate Change

New York State has built a portfolio of programs and policies that will lower energy use, reduce heat-trapping greenhouse gas emissions and prepare for unavoidable climate change. Governor Cuomo has strengthened this portfolio with strategic statewide plans to make New York's energy systems more resilient and reliable and to enhance the State's energy competitiveness (NYS DEC, 2017a).

The goals of the DEC Office of Climate Change are very much in line with the wider State initiatives, and DEC is a major contributor in many of the initiatives set for in the State energy plan and REV. Listed below are some of the more significant GHG reduction goals and how they relate to on-farm anaerobic digestion technology.

- *Goal: Build a resilient and low carbon future for New York.*
- *Goal: Reduce atmospheric greenhouse gases (GHGs) to stay below 2 degrees Celsius of global warming.*

As discussed in detail in the section regarding REV, on-farm AD technology significantly reduces GHG emissions, as the methane produced from manure storages is captured and combusted, and ultimately released as CO₂, which has a 34 times lesser impact on atmospheric warming activities.

- *Goal: Develop market-based solutions to GHG mitigation and climate change adaptation in New York State.*

Already work is being done by the EPA to develop a 'social cost of carbon', this economic expression helps to place a value on damages avoided when a GHG reduction is pursued. As discussed

Municipal food waste may best be utilized by AD on farms. Both the energy produced and the nutrients contained, can be recycled.

Dairy manure acts as an important buffer to regulate the digestion process. This makes on-farm AD ideal to treat food waste diverted from landfills.

AD removes odors and conditions the nutrients to make them more plant available. These factors increase the likelihood that a nutrient management plan will be both accurate and implemented in a timely way.

in the section regarding REV, it was calculated that the unrealized return on investment that farm-based ADs in NY could have had, is over \$5 million USD (Wright & Gooch, 2017). This means that if the benefits conveyed to society by treating manure in these 28 ADS were monetized, the economics of farm ADS would be entirely different, as would a farm's ability to secure funding and loans for project implementation.

- *Goal: Develop cost-effective approaches to prepare for the impacts of climate change.*

Not only are farms a part of the solution to reduce GHG emissions in NYS, but they stand to be one of the entities most impacted by the changes in climate trends. As has already been observed in New York over the past decade, heat stress for dairy cows is negatively impacting milk production and herd health. Heat stress continues to be a major theme in climate resiliency for NY dairy farms. Increased cooling and ventilation in dairy barns is one of the primary heat stress mitigation techniques, however, this method brings with it a significant increase in electricity usage. In order to sustainably manage heat stress mitigation, AD systems can offer a solution, in that they generate renewable energy that is normally first used to offset farm energy usage.

Executive Order No. 24 was the legislative action that created the goal for NYS to reduce GHG emissions 80% below 1990 levels by 2050. This action also created the Climate Action Council, with the directive to prepare a climate action plan. The interim report for this plan contains a vision for the year 2050, and what each sector will look like, having undergone the transformation to operating in a low-carbon economy. The following, is the vision presented for NYS agriculture:

A carbon-negative New York agricultural sector will help to meet the state's food and fiber needs, while also making a significant contribution to the energy supply mix. Farms will be profitable, valued by society, and highly adapted to a changing climate. Farmers will be unable to recall the time when managing single-resource concerns was the norm, or when the number and the area of farms declined each year because single-product farms could not compete in a fossil-fuel dependent world undergoing major climate shifts (NYS CAC, 2010).

Division of Water

The mission of the Division of Water is to protect and conserve the water resources of New York State. This mission is accomplished through a wide range of programs and activities. Some of these are statewide in their scope and apply to all parts of the state. Other efforts are targeted to address water quality and quantity issues in specific regions of the state, focusing on waterbodies or watersheds where these issues are of particular concern.

Farm-based AD contributes to improved water quality on several levels, including:

- **Conservation of crop nutrients** – The anaerobic digestion process does not consume the manure nutrients nitrogen (N), phosphorus (P), or potassium (K) all of which are important for crop production. The ratio of N, P, and K to meet crop nutrient demand will be likely different than digester effluent, thus providing for the opportunity to further process manure for use by plants.
- **Improvement in crop utilization of manure nutrients** – Effluent from digesters can be stored long-term without significant odor problems allowing farmers to apply nutrients to even sensitive field crops in an agronomic, timely fashion, thus reducing the potential for surface water and/or groundwater contamination. Additionally, the specific forms of the crop nutrients N and P are more available for use by planted crops than raw manure, increasing potential nutrient recapture when managed properly.
- **Timing of application** – summer application of AD treated manure can be readily made on hay fields in compliance with CAFO permit requirements and without causing neighbor relations issues. The hay crop is perfectly suited to utilize the additional nutrients, while water quality is protected as the risk of water run-off and leaching is low.

The accumulation of these water quality related benefits lead to enhanced recreation opportunities which has a positive impact on local economies.

Concentrated Animal Feeding Operations (CAFO)

A Concentrated Animal Feeding Operation (CAFO) is an animal feeding operation (farm) that meets certain animal size thresholds and that also confines animals for 45 days or more in any 12-month period in an area that does not produce vegetation. New York State has more than 500 CAFOs, the majority of which are dairy farms with 300 or more cows and associated livestock operations (NYS DEC, 2017b). DEC is the body overseeing permitting for these types of operations, including those dealing with the proper management of nutrients to increase water quality. These permits provide farmers with more certainty regarding their compliance with state and federal laws and regulations by better defining permit terms and conditions (NYS DEC, 2017b).

Winter Weather Applications. Applications of manure, litter, food processing waste, digestate, and process wastewater during periods that meet *winter spreading conditions* as defined in Appendix A, must adhere to the following conditions: (1) Must utilize the 2015 Cornell Guide, “Revised winter and wet weather manure spreading guidelines to reduce water contamination risk”, as well as NRCS NY590 Standard, to develop specific winter application procedures to be included in the CNMP; and (2) CNMP must identify specific low-risk fields to be used for winter weather applications. Lacking any reliable applications during the winter farms will need to include long-term storage as a required practice.

Wet Weather Applications. If applications of manure, litter, food processing waste, digestate, or process wastewater during wet weather, or forecasted wet weather are necessary, recommendations contained in the 2015 Cornell Guide, “Revised winter and wet weather manure spreading guidelines to reduce water contamination risk”, should be followed. In no case can applications be made on saturated soils per Part III.A.8.a.1 of this permit. **(Prohibited Conditions.** (1) Saturated Conditions. (a) Applications may not be made on saturated soils (either fluid-saturated or frozen-saturated soil conditions).

Most CAFO farms require long-term manure storages to reduce the impact on water quality; AD can reduce the odor of stored manure, which allows for summer manure spreading between cuttings, which in turn reduces the need for fall application rates/levels. New permits call for a winter spreading plan which, if the farm is not able to comply with (evidence shows that most are *not* able), then storage will be required. Anticipation is that most all CAFO’s that do not have at least 6 months of storage will be made to increase their storage capacity. This requirement will lead to larger sized storages, increasing the quantity of manure stored long-term, and potentially increasing the length that manure is stored, both of which will likely increase GHG emissions. It is important that within the agency, work is done to form collaborations that work toward meeting all goals in a parallel fashion; meeting one goal (water quality) should not sacrifice the progress towards meeting another (GHG emission reductions).

Division of Materials Management

*The mission of the Division of Materials Management is to protect the environment and public health through fulfillment of two broad goals (the second is pesticides, which is not discussed in this document):
Minimize waste and maximize the use of recyclable materials, while ensuring that solid waste management facilities within the State are operated properly. By capturing the economic value of materials, their imbedded energy is conserved and the generation of greenhouse gases and pollution is minimized.*

The **long term goal** of New York State is to reduce waste disposal to **0.6 pounds per person per day by 2030**, by maximizing waste reduction, recycling and resource recovery and significantly reducing the amount of waste destined for management in a municipal waste combustor or for disposal at landfills. Food processing waste is especially suited for recycling in manure-based AD systems. Utilizing both the energy and the nutrients from the waste and recycling the effluent back to the land, while reducing GHG emissions, should be the goal of the State’s waste management plan. Anaerobic digestion technology used on dairy farms in NYS is a proven, effective synergistic action to accomplish this goal. Other states, including Massachusetts and Vermont have enacted bans on landfilling organic waste, and use AD as an alternate strategy to landfilling. In partnering farm ADs with municipal solid waste (MSW) streams, organic waste can be treated effectively through the incorporation of manure, which acts as a buffering material for high-strength organic wastes. Not only is waste diverted from landfills, but GHG emissions are reduced, and renewable energy is generated in the process.

Municipal solid waste (MSW) generation in New York State, including both materials recycled and waste sent to disposal, was estimated at 5.15 pounds per person per day in 2008 (NYS DEC, 2010). As the recorded population in NYS in 2016 was 8.5 million people, this amounts to 43.8 million pounds of MSW that could potentially be diverted and incorporated into an AD. At this point in time, farm-based AD systems are allowed to incorporate up to 50% by weight, of manure produced on the farm.

2.3 Department of Public Service



AD is recognized as a contributor to the potential renewable energy supply for NYS.

The GHG reduction by AD technology could help to meet the Regional Greenhouse Gas Initiative goals.

AD, even if fully funded and implemented on 364,000 cows, would only increase electric rates by an average of \$0.000542/kWh while reducing CO₂e by 1,084,000 metric tons

The primary mission of the New York State Department of Public Service is to ensure affordable, safe, secure, and reliable access to electric, gas, steam, telecommunications, and water services for New York State's residential and business consumers, while protecting the natural environment. The Department also seeks to stimulate effective competitive markets that benefit New York consumers through strategic investments, as well as product and service innovations.

The PSC is one of the main agencies with responsibility to carry out the REV targets. Section 1.2 outlines all the main areas of the NYS Energy Plan that relate to on-farm AD. REV does specifically call out biogas as a renewable energy source, although it is not mentioned often in the report, here is what the REV says about biogas:

New York is currently exploring and supporting a wide range of innovative biogas-based power generation technologies. Biogas facilities process organic components such as industrial food wastes and manure in an anaerobic digestive process and use the resulting gas (a mixture of primarily methane and carbon dioxide) as a fuel source to create electric power. In addition to creating electricity, anaerobic digestion harnesses greenhouse gases that would otherwise be pollutants.

In October 2016, the next major steps in the REV transition to a clean energy grid, were found to include 'new approaches' to determine the full value of renewable power, and strategies to pursue a more market-based approach to compensating clean, renewable energy sources placed on the grid.

The public service commission is reviewing a proposal to allow farm based ADs to organize with food processors much like Community Distributed Generation (CDG) systems to allow them to use the value stack and distribute their exported power to food processing entities. This may help ADs participate in the REV process but will not (at this time) monetize the full GHG reduction.

2.4 NYS Department of Agriculture and Markets



The agriculture sector in New York State is a significant contributor to the State economy; the State's total agricultural production was valued at over \$5.4 billion annually.

Dairy is the largest segment of the agricultural sector (NYSERDA, 2017a). If all 156 of the large dairy CAFO's in NYS possessed an AD system, they could reduce the manure-based GHG emissions by 81%.

Ag & Markets has programs including: AEM, Ag Non-Point Source Abatement & Control Grant Program, Climate Resilient Farming Program, and the Dairy Acceleration Program (DAP) that may assist dairy farms in GHG control.

The Department, through its various divisions and programs, promotes New York agriculture and its high-quality and diverse products, fosters agricultural environmental stewardship, and safeguards the State's food supply, land and livestock to ensure the viability and growth of New York's agriculture industries.

About 23% of New York State's land area, or 7 million acres, is farmland. There are nearly 36,000 family farms producing some of the world's best food. Agriculture is a major driver of the New York State economy and the State ranks high among the major agricultural states in the nation, ranking in the Top 10 in 30 commodities.

The New York State Soil & Water Conservation Committee works with local Soil and Water Conservation Districts (SWCD) to implement environmental programs. SWCD also work in partnership with federal USDA programs to provide technical and cost-share assistance to implement BMPs. The *Ag Non-Point Source Abatement & Control Grant Program* provides competitive planning and implementation grants to put BMPs on farms that can include anaerobic digesters. Since the program began in 1994 more than \$153 million has been awarded to Soil & Water Conservation Districts across the state to help farmers reduce and prevent agricultural sources pollution. Since the program began in 1994 more than \$153 million has been awarded to Soil & Water Conservation Districts across the State to help farmers reduce and prevent sources of agricultural pollution.

They also administer the NYS Climate Resilient Farming Program. The goal of the CRF Program is to reduce the impact of agriculture on climate change (mitigation) and to increase the resiliency of New York State farms in the face of a changing climate (adaptation). This program capitalizes on the opportunities to mitigate agriculture's greenhouse gas emissions while strengthening the resiliency of New York State's farms. At this time they are developing an addition to the Agricultural Environmental

Management (AEM) program, which includes a series of GHG worksheets that will help farms understand and control GHG emissions from their operations.

The Dairy Acceleration Program operated through the PRO-DAIRY Program at Cornell University College of Life Sciences is an initiative of Governor Cuomo in partnership with Ag & Markets and the NYS DEC designed to enhance profitability of New York dairy farms while maintaining a commitment to environmentally responsible dairy farming.

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Appendix A. Benefits of Anaerobic Digestion

There are many benefits of farm-based anaerobic digestion systems that benefit farmers and non-farmers alike, providing sustainability to the animal agriculture industry by: increasing renewable energy production, increasing the potential for off farm sales of by-products and recycling of nutrients, improving water and air quality, and positioning animal agriculture for the future.

The potential benefits include:

- **Reduction of Greenhouse Gas Emissions** – Cornell applied research has shown that on average for every two cows' worth of manure digested annually, one US car's worth of GHG emissions are removed. There are additional GHG reductions when AD is combined with electric generation and heat production replacing fossil fuel derived energy. The potential for this can significantly increase when other waste organics are co-digested instead of sent to landfills. This is good for the environment and further shows consumers that farmers strive to be good environmental stewards.
- **Odor Reduction** – Manure is commonly stored long-term (6 months or more) to reduce the chance of pollution to water bodies. Long-term storage of raw (untreated) manure releases offensive odor emissions, especially when the storage is agitated prior to emptying and when applied to a farm's cropland. This creates conflicts with other economic development opportunities in rural areas. However, digested manure can be stored and recycled to the farm's land base with far less odorous emissions; less odor allows a farmer to be more flexible in dealing with how manure is stored and recycled to the land base. This flexibility allows the nutrients to be more efficiently recycled on a larger land base without impacting non-farm rural life.
- **Conservation of Crop Nutrients** – The anaerobic digestion process does not consume the manure or co-digested organic nutrients, nitrogen (N), phosphorus (P), or potassium (K), all of which are important for crop production. Recycling of these nutrients appropriately to a land base of growing crops, as opposed to fertilizer purchase, saves money and the energy needed to produce the fertilizers. The ratio of N, P, and K to meet crop nutrient demand is often different than digester effluent, however AD provides for the opportunity to further process manure to partition the nutrients and the moisture contents for more efficient application of fertilizer to both farm and non-farm land.
- **Improvement in Crop Utilization of Manure Nutrients** – Manure application at the times during the year when plant growth is minimal has the potential for nutrient loss. Effluent from digesters can be stored long-term without significant odor problems allowing farmers to apply nutrients to even sensitive crops in an agronomic, timely fashion, thus reducing the potential for surface water and/or groundwater contamination. Odor issues often prevent stored manure from being applied to fields near residences. Additionally, the specific forms of the crop nutrients N and P are more available for use by planted crops than raw manure, increasing potential nutrient recapture when managed properly. Precision feeding for production requires quality forage production. Precision

fertilizer application to achieve high quality forage and higher production per acre will be needed as farms become more efficient in the future.

- **Improvement of Water Quality** – Application of AD treated manure can be readily made in the late spring and in the summer on hay fields in compliance with Comprehensive Nutrient Management Plan requirements and without causing neighbor relations issues. These growing crops are perfectly suited to utilize the additional nutrients, while water quality is protected as the risk of water run-off and leaching is low. There are a number of watersheds under TMDL regulations that include N and P load reductions. To reduce nutrient loading in sensitive watersheds portioning nutrients to specific products is needed. These products would then be available for easier transportation or to crop farms. AD is an important precursor to obtain nutrient partitioning from manure and co-digested organics. Climate change, wetter winters and more intense rainfall, will create even more concern in this area.
- **Generation of Renewable Fuel/Energy** – Biogas can be used to generate electricity and utilize heat as hot water and/or dry materials such as corn and cow bedding, or used in a number of other potential alternative uses that can be used on- or off-farm, including liquid fossil fuel replacement. This distributed renewable energy can be produced at a much steadier rate than both wind and solar. The additional utilization of the energy potential from waste organics significantly increases the energy available during AD.
- **Revenue Potential** – Besides reducing on-farm purchased energy costs for electricity and/or heat, the digester may facilitate other enterprises such as digested manure solids sale as compost or bedding, excess electricity sales, or co-digestion of food waste for a tipping fee. Both green energy and GHG credits are potential revenue sources. Utilizing the methane for resale or as a transportation fuel are also possibilities.
- **Pathogen Reduction** – Cornell research has shown a 99.9 percent reduction of indicator organisms (those that are commonly used to evaluate the success of a system's performance relative to killing pathogens). Food safety, hazard reduction procedures and trace back of pathogen contamination will make this factor much more important in the future for agriculture to remain sustainable in the US. Complete pathogen reduction by pasteurization of portions of the AD effluent is also possible.
- **Pre-treatment** – Anaerobic digestion produces a consistent effluent material (same temperature and pH) that is in a useful form for further treatment including solid, ammonia nitrogen, and phosphorus separation into discrete, usable forms for sale or on-farm use. Energy production from the AD would also provide low cost electric and heat for the additional treatment processes.
- **Co-digestion** – The performance of farm-based digesters is enhanced by adding off-farm substrates. Many of these substrates are costly to dispose of by other means and are not fully utilized for their energy and nutrient values. Society's goal to eliminate organics from landfills will create a need for organic treatment and recycling. Treating these organics with the stability of a manure stream and then recycling the nutrients to the land is a much better alternative than separate compost operations or incorporation into sewage treatment plants.

Appendix B. Background: Anaerobic Digestion Technology

Anaerobic digestion is a technology employed to treat organic wastes, and this specific discussion is focused on the use of this method by dairy farms in NYS. Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels (ABC, 2017). Dairy farms utilize AD, mainly to reduce odors, and possibly to generate on-farm electricity.

Another important aspect of farm-based AD is its ability to accept off-farm waste materials to co-digest with animal manure. Energy production due to the co-digestion process is estimated to be three times that of digesting manure alone. The resulting biogas can be transformed into multiple energy outputs, as discussed.

There are a number of benefits that anaerobic digestion (AD) of dairy manure conveys to the farm and to society as a whole. Historically, the major benefits have included odor control and the potential to generate income from the energy produced and from tipping fees received for imported organic waste co-digested – these and multiple other significant benefits are provided in Appendix A. Despite the many benefits AD offers, it has not been widely adopted by US dairy farms to date since the cost to own and operate an anaerobic digestion system (ADS) generally exceeded the revenues and direct avoided costs. From the perspective of the value of renewable energy produced, the price paid by the utility for the electricity generated has not fully valued the GHG reductions that an ADS is able to deliver. The valuation of all benefits associated with AD is important to determine, in order to promote public policies that expand opportunities to implement renewable energy in New York State (Wright & Gooch, 2017).

Between 1990 and 1998 there were no ADS operating on commercial dairy farms in NYS, however, with the construction of the first full-scale system in 1998, there was an increasing number of systems installed on farms over subsequent years. **Figure 9** depicts the installation history of ADS installed on dairy farms in NYS up to the time this document was written.

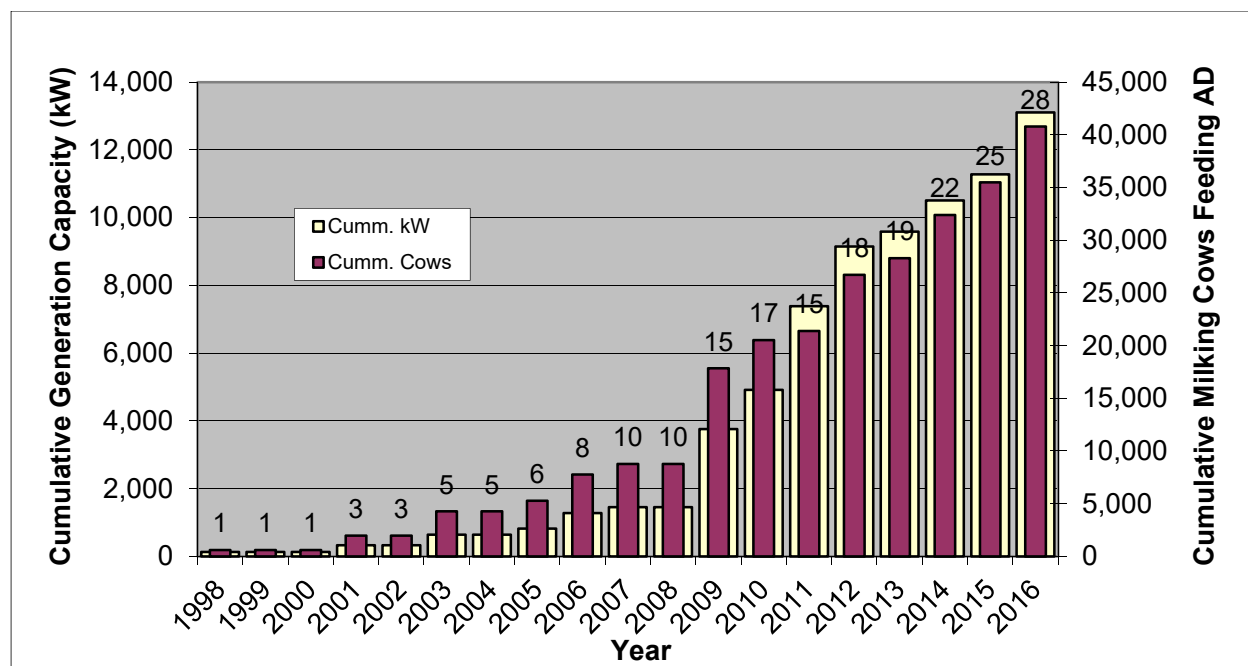


Figure 9. Dairy Cows Supplying Anaerobic Digesters and Associated In-place Generation Capacity (kW) in NYS 1998-2016

Lastly, the implementation of this technology is not without barriers, there are a number of challenges precluding widespread adoption of farm-based AD that have been previously identified. There are also many advanced opportunities that have yet to be pursued by the AD industry in NY. Each challenge and opportunity below is paired with a potential solution to provide examples of what effective policies to support AD expansion.

- Capital Cost** – The typical range of capital cost for a farm-based AD system is between \$1,200 and \$2,000 per cow, and for smaller farms the range is higher. Most farms are not in a financial position to be able to afford this investment. *Funding priorities and the most effective funding mechanisms could be addressed.*
- Total Annual Cost** – The high capital cost and annual cost to operate and maintain the system results in a high total annual cost. *Determine and implement the most effective funding mechanisms to be put in place that would alleviate this burden.*
- Revenue Streams** – The main economic output of digester is currently electrical energy, but the value of this energy is very low when sold at wholesale rates to the grid (currently ~\$0.035/kWh). Farms that co-digest can receive tipping fees for imported substrates, but contracts for such substrates are virtually non-attainable. *Analyze what level of tipping fees are needed to make projects viable and work toward engaging waste producers to develop models for long-term contracts.*
- Return on Investment** – The high total annual cost to own and operate a digester generally exceeds the revenue and displaced cost streams resulting in a negative return on investment.

Investigate programs and incentives (current and future potential) that would provide the appropriate revenue to address this issue.

- **Financing** – Lenders are reluctant to finance digester systems due to their high economic risk. *By better educating lenders about AD technology and developing solutions to address the other financial challenges for farm-based AD, financing mechanisms can be improved.*
- **Utility Interconnection** – Of the farms that have installed digester systems, the significant majority report that the major challenge with their projects was working with the utility to interconnect with the grid in order to be able to sell excess electrical energy generated. *With certain policies in place supporting distributed generation, it will be easier to advocate for AD system interconnection to in turn facilitate adding renewable energy to the grid.*
- **Increasing Renewable Electricity Revenue** - Farms currently operating AD systems are only able to participate in Net Metering until the 20% threshold of the utility's line demand is reached. *Work can be done to address the 20% threshold and increase this limit, allowing additional renewable electricity generation to occur. In addition, investigating a program similar to the "Cow Power" program that exists in Vermont, could yield a higher electricity revenue for Net Metered farm AD systems.*
- **Increase Non-electricity Associated Revenue** – Since the price currently paid for renewable electricity sold to the grid is not enough to make many AD projects economically viable, work needs to be done to diversify sources of revenue for these systems. *There are many synergistic enterprises capable of providing additional income for an AD system. In addition, the growing trend of organic waste diversion offers opportunity for both the farm-based AD industry and NYS food industry to benefit from a sustainable waste management solution.*

Greenhouse Gases

An anaerobic digestion system (ADS) is designed to intentionally produce biogas, and to furthermore capture this gas, which contains approximately 60% methane (CH₄), which can be used to fuel an engine generator-set to combust the CH₄ and to generate renewable electricity. An ADS reduces CH₄ emissions from manure storages by capturing and subsequently combusting the CH₄ and transforming it to carbon dioxide (CO₂), effectively reducing its global warming potential (GWP). An ADS additionally reduces CH₄ emissions by displacing fossil fuels otherwise used to generate electricity used on-farm. The GWP of a gas is a measure of a gas' ability to trap heat in the atmosphere, relative to other greenhouse gases, as compared with the same mass of carbon dioxide. On a 100-yr scale, CH₄ is 34 times as potent as carbon dioxide (CO₂); on a 20-yr time scale CH₄ is 86 times as potent as CO₂ (EPA, 2017a).

Here we'll discuss in detail both ways in which AD reduces GHG emissions.

1. An anaerobic digestion system (ADS) reduces CH₄ emissions from manure storages by capturing and subsequently combusting the CH₄ portion of biogas and transforming it to carbon dioxide (CO₂), significantly reducing its GWP. For reasons relating to the protection of water quality resources, manure storages are State mandated on farms over a certain threshold. However, accumulation of manure and its storage in a mostly anaerobic environment leads to the release of damaging GHGs, namely, methane. Methane is more of a concern to control than CO₂ because of its much larger impact on the warming of the atmosphere. With an ADS, this methane that would otherwise be released is instead captured and subsequently combusted.
2. An ADS additionally reduces GHG emissions by displacing fossil fuels otherwise used to generate electricity used on-farm. When an engine-generator set is used to combust the CH₄ produced by the ADS, the energy generated is first used on-farm to offset electrical or thermal energy needs. This offsets electricity otherwise purchased from the grid, which in NYS mostly consists of fossil fuel-based sources (natural gas, coal, petroleum).

The 'social cost of carbon' is a recently developed term, used to represent the value of damages avoided for a small emission reduction (i.e., the benefit of a CO₂ reduction) (EPA, 2017b). In a paper recently presented at the American Society of Agricultural and Environmental Engineers (Wright & Gooch, 2017), the difference between the baseline condition (4.96 MT CO₂e/cow-year) and the conditions post-implementation of an ADS, were compared to yield the farm's net GHG emissions associated with the implementation of an ADS (3.32 MT CO₂e/cow-year). The US Environmental Protection Agency (EPA)'s social cost of carbon (SC-CO₂) was used to quantify the economic value of the reduced GHG emissions associated with AD. Using the net GHG reduction value and a three-year average SC-CO₂ of \$47.82/MT CO₂ the GHG reduction component of the environmental economic value of farm-based AD (Eghg), expressed on an electrical energy generated basis was \$0.081/kWh.

Distributed Generation

AD biogas is composed of approximately 60% methane and 40% carbon dioxide, and trace levels of other gases (<1%). The methane portion of the biogas holds the energy generation potential, and many farms that employ AD technology as a manure management strategy choose also to combust the resulting biogas in an engine-generator set to produce renewable electricity and to capture excess heat. This resulting renewable electricity is first used on-farm to offset purchases of fossil-fuel based electricity from the central power grid. The remaining power is sold to the grid through a net-metering agreement. The electricity conveyed to the central electricity grid is locally produced, clean distributed energy.

Appendix C. Energy Resources and Statistics

In order to pursue a reduction in fossil-fuel sourced electricity usage, one must determine the current consumption rates and the profile of renewable electricity generation sources in the State. One defining feature of New York State, is that only 11% of the total energy demands were met with generation resources within the State (NYSERDA, 2016). This leaves the State highly dependent on outside sources of electricity generation, which reduces the reliability and future resiliency of the grid system. This weakness can be ameliorated by increasing the presence of renewable generation resources, such as anaerobic digestion technology.

- Renewable resources accounted for 10.8% of the State's primary energy consumption Compared to 9.7% for the U.S. in 2014 (NYSERDA, 2016).
- Energy production from wind, solar, and geothermal resources increased 14.9% from 2013 to 2014 while the collective production of biofuels including ethanol, waste, wood, and landfill gas Increased 1.4% (NYSERDA, 2016).
- In-State resources produced 10.8% of the State's total primary energy requirement, including 6.3% from hydropower and 2.6% from biofuels including ethanol, waste, wood, and landfill gas, collectively. Wind, solar, and geothermal renewable resources met 1.3% of the State's total primary energy requirement. Petroleum and natural gas production accounted for 0.6% of the State's total primary energy requirement (NYSERDA, 2016).

Hydroelectric power and energy collectively from biofuels including ethanol, waste, wood, and landfill gas account for 58.2% and 24.4%, respectively, of the State's in-State primary energy production. Wind, solar, and geothermal resources accounted for 11.7% of the State's in-State primary energy production while crude oil and natural gas constitute the remaining 5.7% (NYSERDA, 2016).

- As of 2011, approximately 90% of the customer-cited capacity originated from solar-PV systems, while only 8% was generated from ADS biogas. The total generation capacity was 157 GWh in 2011, which represents less than 0.1% of New York's total electricity requirement.
- In 2016, 24.13% of New York's electricity was produced by renewable resources. Electricity produced from water, wind, solar and other renewable sources accounted for 33,192 gigawatt-hours (GWh) of the 137,532 GWh of electric energy generated in New York last year (NYISO, 2017).